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Addendum

Final Report

March 1973

Follow-On Analyses

Astronomy Sortie Missions Definition Study

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March 1973

ASTRONOMY SORTIE MISSION DEFINITION STUDY

FOLLOW-ON ANALYSES

Prepared for:

National Aeronautics and Space Administration
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FOREWORD

This document is submitted in accordance with the data requirements of the Follow-On Effort to the Astronomy Sortie Missions Definition Study, George C. Marshall Space Flight Center Contract NAS8-28144, Modification Number 2 and the Data Procurement Document Number 282, Data Requirement MA-04.

This volume is an addendum to the Astronomy Sortie Missions Study Final Report issued in September of 1972. This document contains the results of the follow-on effort and does not cover the results of the original Astronomy Sortie Missions Definition Study which are contained in the four volume final report issued in September of 1972.

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I. INTRODUCTION

This document includes the results of the design analyses, trade studies, and planning data that were developed during the 6-month follow-on effort to the Astronomy Sortie Mission Definition Study, Contract NAS8-28144. This study was performed for the George C. Marshall Space Flight Center by an industry team led by the Denver Division of Martin Marietta and supported by the Bendix and Itek Corporations. The Bendix Corporation was responsible for the pointing, control, and stabilization analyses for the astronomy instruments and for the Shuttle stabilization system. The Itek Corporation was responsible for the definition of the astronomy instruments and the analyses of their performance and operations.

To understand the information contained in this document it is necessary to have the background information that was derived during the original 9-month Astronomy Sortie Mission Definition Study. This information is contained in the four-volume final report (Ref 1).

The primary objective of the 6-month follow-on effort was to provide more in-depth analyses of several key areas identified during the original study. A summary of each of the key areas is presented in the following paragraphs.

UV Instruments - The purpose of this task was to analyze and conceptually define a group of small ultraviolet (UV) instruments, and to define the support hardware and operations necessary to accommodate the instruments. As a result of this task, eight small UV instruments that might be flown on the sortie missions were identified. It was recommended that these instruments be designated as "flight of opportunity" instruments that could be flown on any inertial attitude sortie mission that had excess cargo bay volume and payload weight capability. The support hardware defined was based on the "flight of opportunity" mode of operation, and the major piece of support hardware identified was an instrument mount that would house instruments up to 1.17 meters (46 in.) in diameter.

Nondeployed Solar Payload - The purpose of this task was to evaluate solar payload configurations that do not require deployment of the entire payload out of the cargo bay. Based on the analyses performed, we recommend a solar payload configuration that does not require deployment, and hence does not require a deployment mechanism. In addition, we recommend stabilizing the Shuttle orbiter in a Z-POP inertial attitude (Shuttle's longitudinal axis lies in the orbit plane with the Z-axis perpendicular to the orbit plane) throughout the 7-day mission.

On-Orbit Access - The objective of this task was to investigate several alternative methods of providing on-orbit shirtsleeve access to the focal planes of the infrared (IR), stratoscope, and photoheliograph telescopes. The recommended approach for providing the on-orbit shirtsleeve access is a configuration where the telescope optics are in the vacuum environment external to the Sortie Lab, and the focal plane instruments are located in the Sortie Lab. Light is brought from the telescope optics through a passage in the Sortie Lab bulkhead and made available to the instruments. A mechanical gimbal provides 2 degrees of wide angle pointing, and fine pointing and stabilization is obtained by image motion compensation within the telescopes. During the study, the IR telescope was dropped from consideration for on-orbit access because of the potential problems associated with the cryogenic temperatures.

Planning Data - The planning data developed include the cost and schedules associated with the astronomy instruments and/or their support hardware.

Cost Estimates - The costs are defined in terms of DDT&E, production, and operations, and are presented in a parametric fashion that will allow any payload or payload combination to be costed.

II. STUDY OBJECTIVES

The specific objectives of this study were:

1) Analyze and conceptually design a group of small survey-type UV instruments and define the support hardware and operations necessary to accommodate these instruments during the Astronomy Sortie Missions. The UV instruments baselined for the study were the Tifft, Morton, and Carruthers instruments that were designed for the ST-100 platform. In addition, derivatives of these baseline instruments were to be investigated for applicability to the sortie missions. The support hardware to be defined was the ancillary hardware that was required in addition to the Sortie Lab and pallet. The operations to be defined included all phases of the mission including ground, prelaunch, launch, on-orbit, and postflight operations;

2) Evaluate the desirability of deploying payloads out of the Shuttle cargo bay. The objective was to examine the requirement for rotating the entire solar payload through a 90-degree angle in order to satisfy the viewing requirements. This task was initiated because of a change in the ground rules requiring that the deployment mechanism weight (approx 2000 lb) and volume (approx 5 linear ft of cargo bay) be charged to the payload. Previously, the weight and volume were charged to the Shuttle orbiter;

3) Evaluate the advantages and disadvantages of providing on-orbit shirtsleeve access to the focal planes of the IR, stratoscope, and photoheliograph telescopes. The primary reason for this task was the strong desire by the scientific community to have on-orbit access to the focal planes of the telescopes. Consequently, several alternatives were to be investigated that would provide this capability;

4) Provide parametric planning data that will enable alternative flight schedules and instrument complements to be evaluated. Because this study does consider representative type astronomy instruments and "straw-man" flight schedules, it was desirable to develop the planning data in a parametric fashion that would allow rapid evaluation of many alternatives.

III. GUIDELINES AND PRINCIPAL ASSUMPTIONS

The guidelines and principal assumptions for the study were provided by the NASA/MSFC Contracting Officer's Representative as a part of the contract statement of work. They were:

1) The Astronomy Sortie Missions Definition Study Final Report (Ref 1) was the baseline for the follow-on effort;

2) The Sortie Can Conceptual Design document (Ref 2) was the baseline for the definition of the Sortie Lab and pallet;

3) The Space Shuttle Baseline Accommodations for Payloads document (Ref 3) was the baseline for the definition of the Space Shuttle interfaces and capabilities;

4) The UV instruments that were to be considered during the follow-on effort were those instruments designed for operation with the ST-100 platform and included--the UV camera proposed for use in the UV photographic survey experiment by Dr. Tifft at the University of Arizona, the all-reflective spectrograph proposed for the UV stellar spectrometry experiment by Dr. Morton of Princeton University, and the Schmidt image converter spectrograph proposed for use in the far UV spectrometry experiment by Dr. Carruthers at the Naval Research Labs;

5) The operational mode for the sortie missions was 7 days duration with two scientific crewmen available for 24-hour-per-day operation of the experimenter.

IV. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

The general results of the follow-on effort are: designate the small UV instruments for the astronomy sortie missions as flight-of-opportunity instruments, and provide accommodations for these instruments using state-of-the-art ancillary hardware; do not require deployment of the astronomy payloads from the Shuttle cargo bay; and provide on-orbit access to the focal planes of the photoheliograph and stratoscope payloads at a modest increase in cost and weight.

The specific tasks that are covered in this chapter include: UV Instruments; Nondeployed Solar Payload; On-Orbit Access; and Planning Data.

A. UV INSTRUMENTS

The emphasis during the follow-on study was on the Sortie Mission concept and its adaptability for providing the means to conduct UV experiments. NASA-MSFC identified a group of small UV survey type telescopes as representative telescopes to be flown. The first task in the study was to examine the experiment definitions contained in the available documentation on these telescopes with emphasis on the aspects that would affect the Astronomy Sortie Mission Definition Study. Itek was responsible for examining the experiments proposed and comparing them with other small or medium sized astronomy instruments formerly associated with rocket flight, balloon, or small unmanned satellite programs. Bendix performed the comparison of pointing and stabilization requirements of the instruments with the available performance data on the NASA-MSFC ST-100 Stellar Instrument (SI) platform. An alternative configuration for an instrument platform and mount was also considered. Mission profiles for the UV survey instruments were established to cover all mission phases, identifying those operations that influence the instrument, Sortie Lab, Pallet, or Shuttle designs or interfaces.

1. Ground Rules and Assumptions

The principal ground rules and assumptions that were used during the performance of this task were provided by the NASA/MSFC COR, or were carried over from the earlier portion of the study. They were:

1) The baselined UV survey instruments consisted of the ST-100 stellar payload experiments. These experiments were considered as representative types of UV telescopes that might be flown. The original group consisted of--the two 15-centimeter (6-in.) survey imaging cameras developed by Dr. Tifft at the University of Arizona (Ref 4), the objective grating telescope developed by Dr. Morton of Princeton University, and the Schmidt telescope for spectroscopy developed by Dr. Carruthers at the Naval Research Laboratory;

2) Other instruments, particularly those designed for rocket flight and balloon-borne interfaces were considered;

3) Detailed designs of the proposed UV instruments were the subject of other studies or programs;

4) Photographic film was the preferred recording media to be used with each experiment;

5) Film cassettes would be loaded with sufficient film to make inflight replacement unnecessary during the 7-day mission.

2. Instruments Considered

In the period since the ST-100 experiments were first conceived, other small telescopes have been proposed or flown that could fulfill the UV experiment mission objectives. Dr. Carruthers has a proposal for a modified Schmidt image-converting spectrograph, which is a larger aperture version of his original instrument and provides increased capability. He has also proposed two 40-centimeter (15.8-in.) complementary telescopes that provide simultaneous spectroscopy and imagery. The physical configuration is similar to the original survey imaging (Tifft) cameras. A coordination meeting with Dr. Tifft at the University of Arizona indicated that an aperture increase for the survey imaging cameras would logically provide a times two magnification to allow use of 70 mm film. Alternatively, the film would remain 35 mm and the aperture increase would be used to decrease obscuration. The all-reflective spectrograph developed by Dr. Morton has been superseded by a larger payload for the Aerobee 170 rocket. This payload has a larger aperture, narrower field-of-view UV Echelle spectrograph. In addition, a balloon-borne instrument, a narrow-band scanning spectrometer described in NASA's Blue Book, Volume III, Section 1 (Ref 5), was considered as a candidate instrument for the Astronomy Sortie Mission. These instruments could fly on a Shuttle

Sortie mission to perform celestial surveys and provide a baseline concept for a sky survey capability. Performance characteristics and accommodation requirements are shown in Table IV-1 for the baselined experiments and for the similar small and medium size UV telescopes.

a. Tifft 15-Centimeter (6-in.) Survey Camera - The UV photographic survey provides high quality photographic images of star fields and emission regions taken in UV light from 1700 to 3000 Å (170 to 300 nanometers). The camera system consists of twin UV cameras, which are identical except for the internal filtering used. One camera operates in a near-UV band (2300 to 3000 Å); the other operates in the mid-UV band (1700 to 2100 Å). Primary emission features to be studied are the Magnesium II doublet at 2800 Å, and the Calcium III intersystem line at 1909 Å. The stellar continuum observations will enable the UV energy distribution of a large number of stars of Spectral Type F or earlier to be examined, and will also provide a general classification scheme based on image photometry. Three exposures will be taken in each band (camera). A wide-angle (20 to 30 deg) star-field camera will be used with the UV survey cameras to take one exposure for each exposure cycle of the UV experiment in order to assist in identifying the field of view. A sun sensor will detect the presence of the sun or bright Earth, with 30 degrees of the look angle of the experiment.

b. Morton All-Reflective Spectrograph - This far-UV stellar spectrometry experiment uses an all-reflective instrument with an objective grating and Lithium Fluoride coated optics. The spectral range observed will be from 900 to 1800 Å (90 to 180 nanometers) with dispersion spectra of O, B, and A stars down to the sixth magnitude. Recording will be on photographic film with a resolution of 0.5 Å. The spectrograph has a 6-degree field of view. When the instrument is tracking the desired source, shutters will be opened and UV-sensitive film will be exposed for a period of 10 to 20 minutes. An ion chamber will be included to monitor the local flux of UV at 1216 Å in the direction of the source. If local flux is high, the experiment exposure duration will be shortened to prevent film fogging.

c. Carruthers Image-Converting Spectrograph - This far-UV stellar spectrometry experiment uses a Schmidt-type electronic image converter with objective gratings. The objective of this experiment is to obtain spectral and photometric data in the far-UV range by means of wide-angle (15 deg) sky surveys using electronographic techniques. The sensitive region of the spectrum will be from 1200 to 1800 Å (120 to 180 nanometers) with data recorded on a nuclear emulsion film. Exposure durations of 2.5, 6.25, 15, 40, 100, 250, and 625 seconds will be used. Analysis of the data will allow determination of the far-UV brightness and spectral distributions of a large number of early-type stars. The experiment

Table IV-1 Small UV Instruments

PARAMETER \ INSTRUMENT	6-INCH SURVEY CAMERAS	ALL-REFLECTIVE SPECTROGRAPH	IMAGE-CONVERTING SPECTROGRAPH	IMAGE-CONVERTING SPECTROGRAPH	INTERNAL GRATING SPECTROGRAPH	IMAGING CAMERA	ECHELLE SPECTROGRAPH	SCANNING SPECTROMETER
Spectral Coverage-Nanometers	170 to 300	90 to 180	120 to 180	30 to 210	90 to 180	90 to 210	120 to 230	270 to 300
Type	Meinel-Shack	Prime Focus	Schmidt	Schmidt	Cassegrain	Cassegrain	Prime Focus	Cassegrain
Aperture-Centimeters	15	5	10	15	40	40	15	40
F/Number	2	2	1.5	2	10	6	5	7.5
Field of View-Radians (deg)	0.08 (5)	0.21 (12)	0.26 (15)	1.7×10^{-1} (10)	1.7×10^{-2} (1)	2.8×10^{-2} (1.6)	1.7×10^{-2} (1)	8.8×10^{-3} (0.5)
Sensor	Film	Film	Electronograph	Electronograph	Electronograph	Electronograph	Film	Image Dissector
Angular Resolution, Radians (sec)	7.3×10^{-5} (15)	14.5×10^{-5} (30)	9.7×10^{-5} (20)	7.3×10^{-5} (15)	5×10^{-6} (1)	5×10^{-6} (1)	--	9.7×10^{-6} (2)
Size-Meters (in.)	0.4 x 0.3 dia (16 x 12 dia)	10 x 0.56 x 0.3 (39 x 22 x 12)	0.89 x 0.53 x 0.28 (35 x 21 x 11)	1.4 x 0.8 x 0.4 (55 x 22 x 16)	1.7 x 0.5 - dia (67 x 19.7-dia)	1.3 x 0.5-dia (51 x 19.7-dia)	1.5 x 0.4-dia (59 x 16-dia)	1.5 x 0.5 x 0.5 (59 x 19.7 x 19.7)
Weight-Kg (lb)	75 (166)	55 (122)	46 (101)	40 (88)	60 (132)	60 (132)	80 (176)	96 (212)
Power-Watts	75	56	20	30	--	--	150	75
Pointing Accuracy, Radians (min)	29×10^{-4} (10)	29×10^{-4} (10)	29×10^{-4} (10)	5.8×10^{-4} (2)	29×10^{-4} (10)	29×10^{-4} (10)	--	0.6×10^{-4} (0.25)
Stability-Radians (sec) Duration-seconds	5.8×10^{-5} (12) 60 - 900	5.8×10^{-5} (12) 120 - 1200	5.8×10^{-5} (12) 2.5 - 625	5.8×10^{-5} (12) 2.5 - 625	5×10^{-6} (1) 60 - 900	5×10^{-6} (1) 60 - 900	4.9×10^{-5} (10) 120 - 1200	5×10^{-6} (1) 15 - 600
Reference	Tifft	Morton	Carruthers	Carruthers	Carruthers	Carruthers	Morton	Kondo

data will help in determining effective temperatures, chemical compositions, and sources of opacity in these stars. Quantitative measurements of the absorbing properties, composition, density, distribution, and temperatures of gases composing the interstellar medium (including galactic nebulae) will also be made.

d. *Carruthers (Modified) Image-Converting Spectrograph* - This experiment will be a modification of the far-UV stellar spectrometry experiment described above. The aperture has been increased from 10 to 15 centimeters, spectral coverage has been expanded to include 300 to 2100 Å (30 to 210 nanometers), and angular resolution is improved to 7.3 x 10^{-5} radians (15 sec). The instrument will be physically larger and will accommodate improved features, such as a removable slit collimator for diffuse source spectroscopy, a rotating mount to introduce three different gratings into the energy path, and a sliding holder for Schmidt correctors.

e. *Carruthers 40-Centimeter Telescopes* - This experiment incorporates two 40-centimeter aperture telescopes, one to perform spectroscopy, the other to perform imagery at the same time on a common target. The internal-grating electronographic spectrograph will cover the spectral range of 900 to 1800 Å (90 to 180 nanometers). It will be mounted at the focus of a Cassegrain-type telescope, which will be equipped with an internal star tracker system that will pivot the Cassegrain secondary mirror to keep the observed image on the spectrograph slit. Field of view for the spectrographic telescope will be 1.7 x 10^{-2} radians (1 deg). The imagery telescope will use a semitransparent-photocathode electronographic camera to obtain an image of the source. The camera will be placed at the focus of a Ritchey-Chretian or Cassegrain telescope. Interchangeable photocathodes will be used with a rotating holder to provide spectral coverage from 900 to 2100 Å (90 to 210 nanometers). An externally generated error signal can be used to correct for pointing jitter by modulating the voltage on the deflection coils around the image tube. Field of view for the imagery telescope will be 2.8 x 10^{-2} radians (1.6 deg). The telescopes will provide complementary data, and will be mounted on a common platform. Angular resolution of either telescope will be 5 x 10^{-6} radians (1 sec).

f. Morton UV Echelle Spectrograph - The 15-centimeter aperture Echelle Spectrograph is an updated rocket-borne version of the Morton spectrograph described above. Spectral coverage for this instrument has been shifted and expanded to cover 1200 to 2300 Å (120 to 230 nanometers); field of view has been reduced to 1.7 x 10^{-2} radians (1 deg).

g. Kondo Scanning Spectrometer - The telescope spectrometer is a versatile, high-resolution system for analyzing stellar UV spectra over a range of 2700 to 3000 Å (270 to 300 nanometers). The instrument (an adaptation of a balloon-borne instrument) will be used to investigate unique emission features, such as the Magnesium II doublet of 2795 Å and 2802 Å (279.5 and 280.2 nanometers), or the Carbon IV and Silicon IV emission lines in the far UV. A fine scanning mode will be used for observing narrow absorption lines, such as those caused by interstellar molecular hydrogen. The Ebert-Fastie grating-optics configuration of the spectrograph will provide a spectral resolution of 0.1 Å. The telescope will use a tilted aplanatic Cassegrain optical configuration, and will provide an angular resolution of 9.7 x 10^{-6} radians (2 $\widehat{sec}$).

3. Mission Analysis

The intent of the small astronomical UV instruments is primarily to study the complete celestial sphere at wavelength ranges not observable by ground-based instruments. Results of the study will be used to establish a dependable base of reference data and to make it possible to identify unusual celestial sources. Generally, the UV instruments do not impose restrictions on mission orbit altitude or inclination with respect to the equator.

Missions are required at various times of the year to permit survey of the entire celestial sphere and to view along the entire Galactic plane. Maximizing dark time is very important to the UV instruments (except the Kondo Scanning Spectrometer).

a. Operational Constraints - Viewing of the celestial sphere by the UV instruments is restricted about the sun, Earth, and moon, and to the dark-time period of the orbit. In addition, targets of interest for several of the instruments lie about 15 degrees from the Galactic plane. Figure IV-1 shows the viewing restrictions and the position of the galactic plane for an orbit on July 15, 1977, during a new-moon condition.

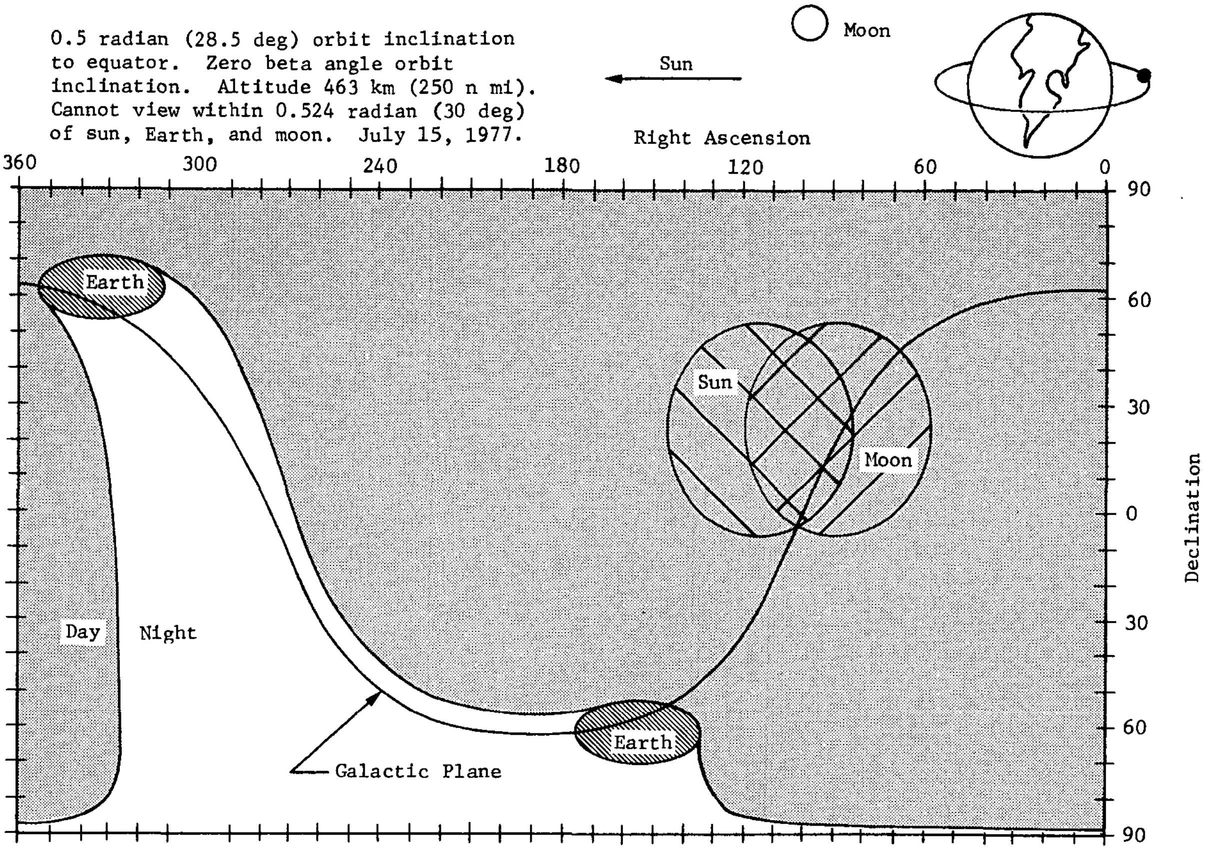

Figure IV-1 UV Celestial Sphere Viewing

The orbit inclination to the Earth's equator is 0.5 radian (28.5 deg) with a zero Beta angle orbit inclination. The altitude is 463 kilometers (250 n mi). The shaded areas that cannot be viewed about the sun, Earth, and moon are the limits of 0.524 radian (30 deg). For the Kondo Scanning Spectrometer, which has view limits of 0.79 radian (45 deg), each of these restricted zones will be 0.26 radian (15 deg) larger in radius than shown. However, the Kondo instrument (unlike the other UV instruments) may view in daylight, so the impact of the larger viewing limits is offset somewhat. For the UV instruments with the 0.524 radian viewing limit, data may be acquired only while in the dark side of the orbit. The viewable portion of the celestial sphere due to this restriction is indicated. It may be noted that at other times of the year the position of these restrictions will be different. Thus, by flying at other times, the entire celestial sphere may be observed and specific targets of interest near the Galactic plane may be viewed.

The nighttime only viewing period and the 0.524 radian (30-deg) look-angle constraint about the Earth are shown in Figure IV-2 for a 463 kilometer (250 n mi) orbit.

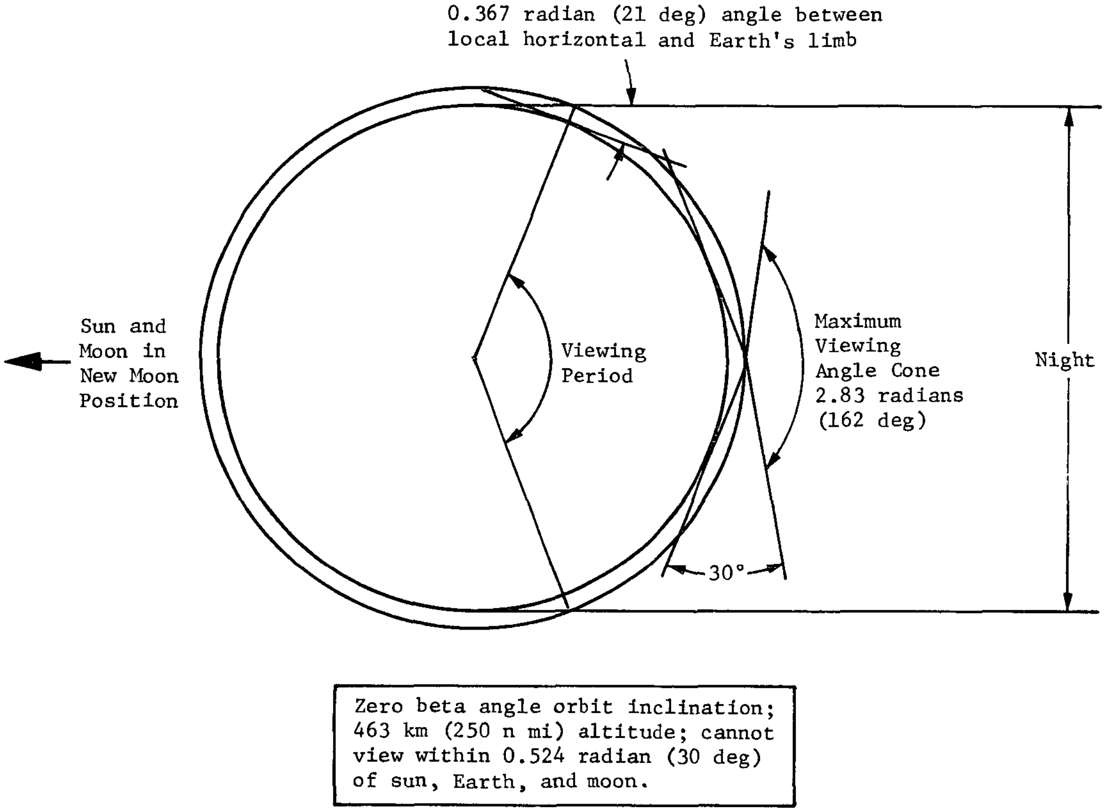

Figure IV-2 UV Viewing Constraints

At the altitude shown, the angle between the local horizontal and the Earth's limb is 0.367 radian (21 deg). Since the UV instruments must view no closer than 0.524 radian (30 deg) of the Earth, the maximum available is a full-angle cone of 2.83 radians (162 deg), which is derived by accounting for the 0.367 radian (21 deg) angle between the local horizontal and the limb of the Earth, as well as the 0.524 radian (30 deg) limit to the limb imposed on the UV instruments. For the Kondo Scanning Spectrometer, the viewing limits are 0.79 radian (45 deg), and the resulting viewing cone is 2.31 radians (132 deg). With the sun and moon in new-moon condition as shown, the 2.83 radians (162 deg) viewing cone is available whenever the spacecraft is in the night view period. With a zero beta angle orbit inclination, the maximum duration of this night viewing period is about 35.3

minutes for an overall orbit period of 93.7 minutes. The constraint of operating these instruments only while in the dark period of the orbit has the greatest impact on the amount of scientific data that may be acquired. This constraint applies to all of the UV instruments analyzed except the Kondo Scanning Spectrometer. The limitation of viewing no closer than 0.524 radian (30 deg) to the sun, Earth, and moon, can be observed without reducing useful data.

b. Survey Operations - While the survey instruments have what is considered wide fields of view from the astronomical standpoint (4 to 15 deg), each exposure sequence on one source region covers only 0.006 to 0.03 steradian. Several of the UV instruments have an objective to survey the entire celestial sphere. Figure IV-3 shows the number of fields in the celestial sphere for various full-cone fields of view.

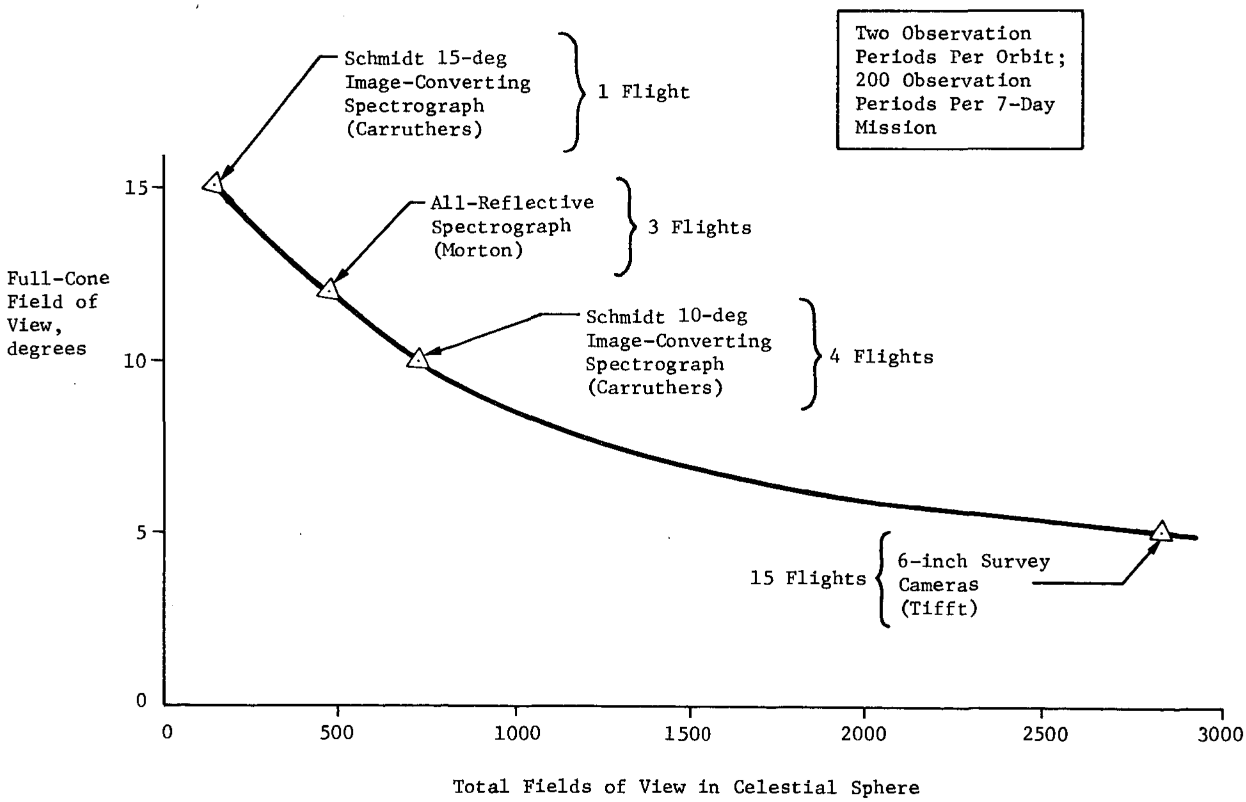

Figure IV-3 Instrument Survey Operations

Four of the instruments that have been proposed are indicated on the figure, together with the number of flights required to complete the survey for that telescope. In making these calculations, the individual fields were overlapped in a hexagonal pattern to provide full coverage and coordination between areas. Two observation periods per orbit were assumed, with a total of 200 observation periods in each 7-day flight. Note that full-sky is practical in sortie missions for all fields of view greater than about 5 degrees. For narrow fields of view, the number of flights required is greater than 15. Note that in a galactic survey program, no high-rate maneuvers of the vehicle are required. The exposure program can be carefully prepared so as to require only slight spacecraft maneuvers between exposure sequences, or even no maneuvers at all.

Another special objective for the small UV instruments cannot be preplanned. Of critical astronomical interest is whatever data can be obtained during the early phases of novae ("exploding" stars) in the photon energy ranges not available to ground-based instruments. Should a survey mission be in progress when a bright nova is detected, the survey program would be abandoned in favor of a detailed study of this unusual object, with all available instrumentation. However, this may also require sizable vehicle maneuvers. To minimize the time lost to reorient the instruments, it appears to be preferable to provide as much of this reorientation as possible with the platform gimbals, and limit the spacecraft reorientation to a roll angle change. This leads to the same platform mounting arrangment considered for the X-POP-I mode, where the wide-freedom gimbal axis is mounted perpendicular to the Shuttle longitudinal axis.

c. Orientation Requirements - The full-hemisphere requirement for instrument orientation results in some specific acceptable platform/spacecraft arrangement, depending on the orbital attitude of the Shuttle. The case where the Shuttle is maintained in a fixed inertial orientation, with the longitudinal axis perpendicular to the orbital plane (X-POP-I) was considered first. The only spacecraft orientation freedom available in the roll axis, i.e., the payload bay can be oriented so that it opens out to any direction in the orbital plane. Since the ST-100 platform has only one gimbal axis with wide freedom, the instrument lines of sight must be perpendicular to this platform axis, and the platform gimbal axis itself must be perpendicular to the spacecraft roll axis. More specifically, it means that the gimbal axis with wide freedom must be oriented parallel to the direction of the Shuttle wings. This provides the possibility to orient the line of sight in any direction in the celestial sphere, by a combination of platform gimbal angle and Shuttle roll angle.

If the Shuttle is maintained in a fixed inertial orientation, but with the longitudinal axis in the orbital plane (X-IOP-I), the payload bay can be oriented so that it opens out toward any direction in the celestial sphere by a combination of spacecraft roll and a rotation of the Shuttle longitudinal axis within the orbital plane. This means that instruments looking out of the payload bay can be oriented to any direction without the need for wide gimbal freedom on the stabilizing platform. Therefore, if no additional constraints on Shuttle orientation arise from other instruments in the payload bay (or from some currently undefined system requirements), the limited-freedom platform orientation capability relative to the Shuttle spacecraft axes is not a constraint. If external constraints exist that limit the spacecraft freedom within the X-POP-I or X-IOP-I attitudes, it does not appear that a platform like the ST-100 with a single-wide-freedom axis can be efficiently used to carry the UV instruments. Noninertial attitudes, such as the X-POP-ZLV or X-IOP-XLV, are not easily handled by a platform with limited gimbal freedoms. In this case, where the spacecraft is rotating at approximately 1.16 mrad sec^{-1} (4 deg/min), the ±15-degrees-freedom axis could limit exposure sequences to less than 10 minutes.

d. Launch Constraints - Figure IV-4 shows the variations in launch window for 463 kilometer (250 n mi) altitude orbits at various inclinations that will result in averages of 15 and 30 minutes of dark time per orbit.

The dark-time periods are averaged over the entire 7-day mission; therefore, some individual orbits in a mission may have the maximum dark-time duration attainable of about 35 minutes, while others have no dark time at all. Note that for 15 minutes average dark time, there is no restriction on launch time at an orbit inclination of 28.5 degrees. At 60 degrees, there is no restriction for about 40 days at both of the equinoxes, and, at the solstices, about 21.5 hours in each day are available for launch. At 90 degrees inclination, the launch window is nearly constant throughout the year, varying from about 17.9 hours to about 18.4 hours per day. To achieve 30 minutes average dark time, a restriction in launch time for an orbit inclination of 28.5 degrees must be observed for about 40 days at the summer and winter solstices. The launch window in this instance is about 22.7 hours. At 60 degrees, the minimum launch window is about 17.7 hours, increasing to about 24 hours at the equinoxes. For 90-degree inclined orbits, the launch window is from about 8.7 hours to about 10 hours for the 30 minute dark-time case. It may be observed that for flights in which the primary experiments do not require other launch times, the launch windows for all orbit inclinations to provide 30 minutes average dark time are not unduly restrictive. The worst limit leaves about 8.7 hours available for launch each day, and in most cases, the launch window is 18 or more hours per day.

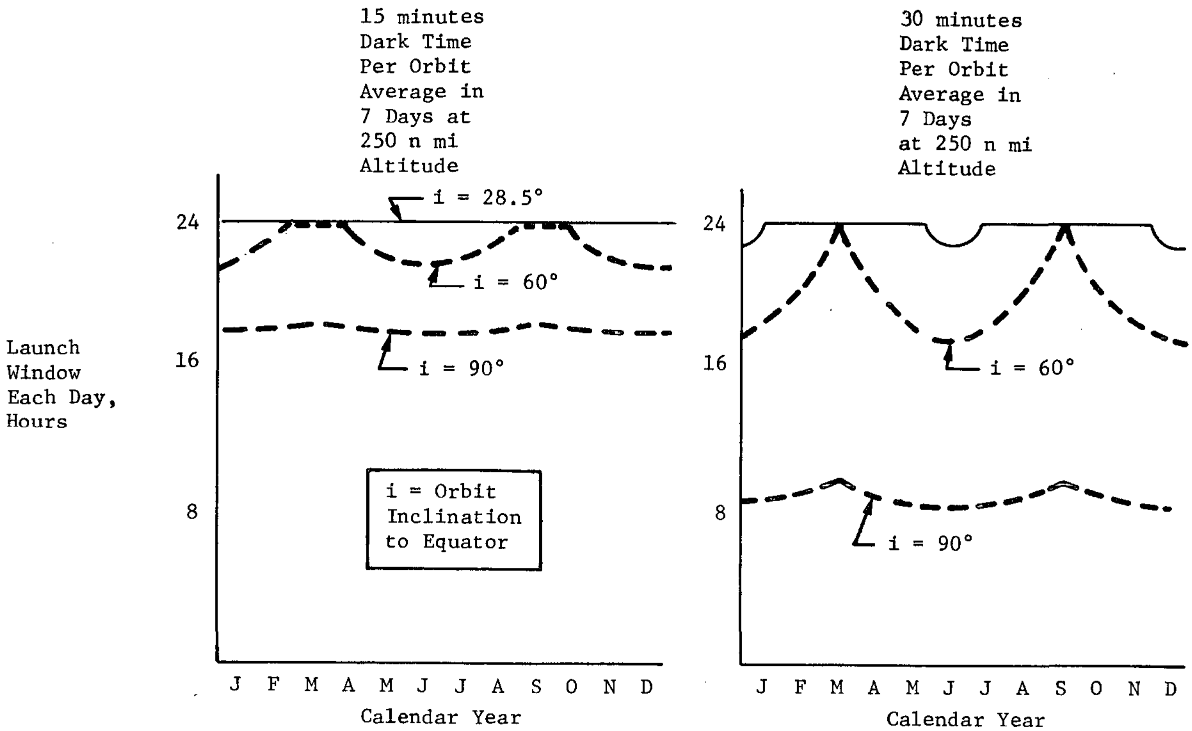

Figure IV-4 Launch Window Variations with Inclination and Time of Year

e. On-Orbit Operations - Typical on-orbit operations sequences for the three ST-100 UV instruments (Tifft, Carruthers, and Morton) are shown in Figure IV-5.

The overall cycle starts for a selected target as the spacecraft enters the dark period of the orbit. Note that this cycle is arranged to provide relatively short exposures using the Schmidt Image Converter Spectrograph, and that the other instruments are coordinated with the Schmidt Spectrograph during the medium- and long-duration exposures. It is necessary that film advance for the three telescopes be performed simultaneously, as shown, when imaging by two or all of the instruments is concurrent. This necessitates the idle times when exposures are not of equal durations. On completion of one cycle, a second target is selected and a portion of the cycle is performed until the spacecraft leaves the orbital dock period. For orbits with less than 28 minutes dark time, the cycle may be shortened to the available time.

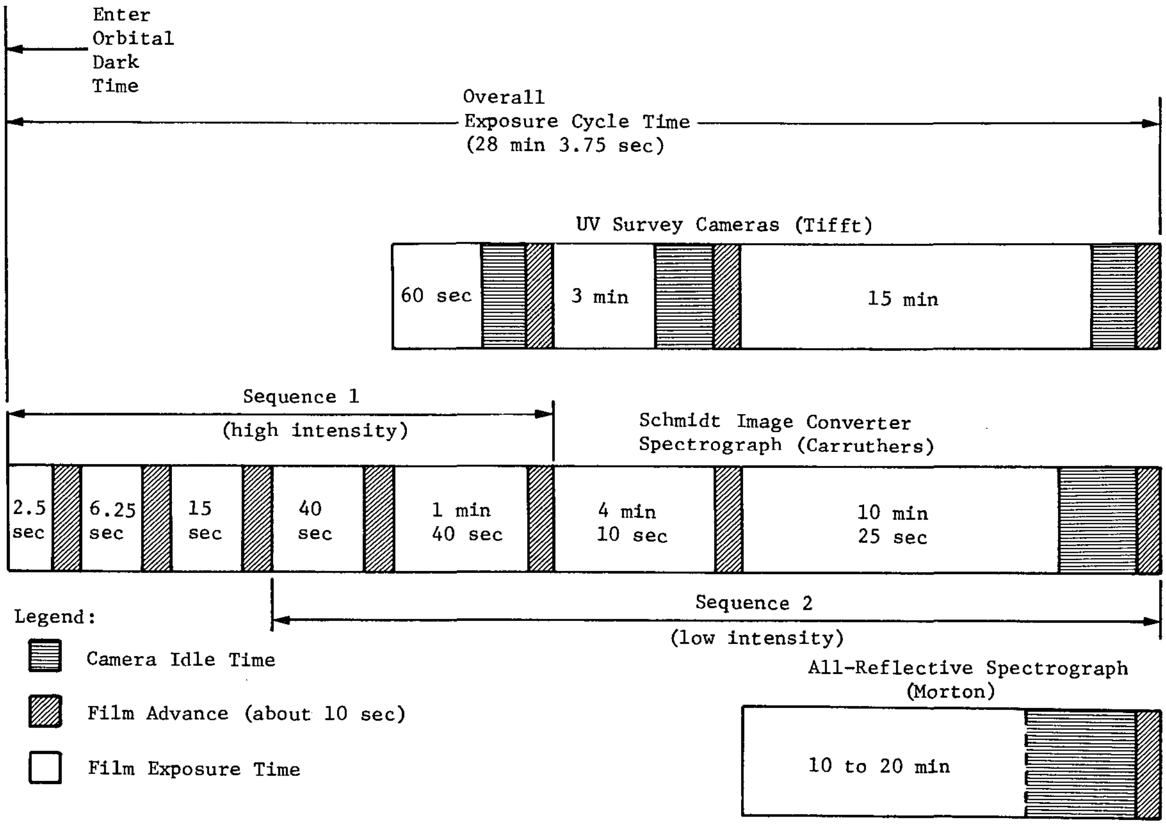

Figure IV-5 UV Instrument On-Orbit Operations Cycle

f. Instrument Refurbishment - The schedule of events required for refurbishing the UV instruments has a duration of 10 weeks (land-to-land), as shown in Figure IV-6. In addition, a post-flight period of 16 weeks has been provided for scientific data processing and analyses, and for planning subsequent missions using these instruments.

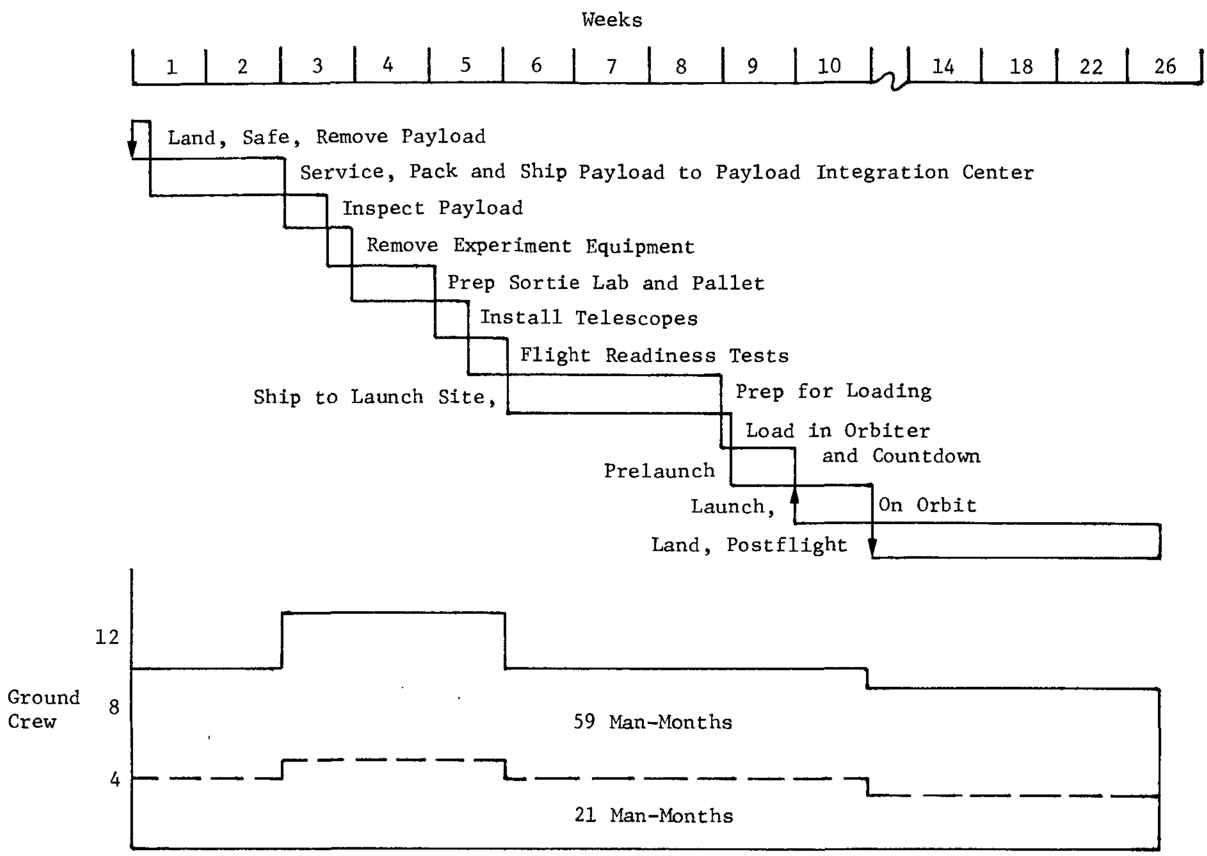

Figure IV-6 UV Instrument Refurbishment

The minimum manpower estimates shown are for a three-man crew dedicated to one UV instrument for the entire turnaround period, including postflight evaluation. During the land-to-land time period, another specialist is required to interface with the Sortie Lab and pallet. During instrument removal, installation, and test at the Payload Integration Center, an integration specialist is also necessary. The maximum manpower estimates are based on a UV flight configuration including three instruments. In this case, three crewmen are dedicated to each instrument over the entire 26-week period, with one specialist to provide the coordination for all instruments with the Sortie Lab and pallet. Three additional men (one for each instrument) are required during operations at the Payload Integration Center.

4. Mission Mode Alternatives

The UV instruments may be flown on compatible Shuttle sortie missions that can accommodate the instruments and the mount. As presently conceived, these instruments require an inertially-stabilized orbiter and minimal crewman participation to perform nonrepetitive and periodic monitoring functions. Orbit constraints and look-angle restrictions are not harsh, but launch window limits may be desirable, depending on orbit inclination and time of year of the mission. Two modes of operation were considered during the study.

The first mode considered was a dedicated flight where the experiments and platform would be used on flights that were programmed for their use. The scientific crewmen would be trained, and given time to interface with the survey telescopes using an airlock integral with the Sortie Lab. The second mode considered was to use the platform and instruments on a flight of opportunity, such as an Earth resources mission or with a biology experiment. A flight of opportunity would imply a minimum of crew training on platform operation, almost no control and display requirements, and no EVA for data retrieval. The crew would be expected to deploy and store the platform and start the experiment, but operation would then be entirely automatic.

a. *Configuration Alternatives* - The three original ST-100 experiments and the five additional experiments were considered for performance and physical compatibility. Each experiment could be flown individually. Two groupings of experiments were considered: one group consisted of the original ST-100 package; the second contained the two Carruther's 40-centimeter telescopes. The experiments and their groupings were reviewed to determine their adaptability for use in the Sortie Lab airlock, with the ST-100-SI platform, or on an outer gimbal platform.

A study was made to determine the feasibility of locating the ST-100 platform in the Sortie Lab airlock defined in "Sortie Can Conceptual Design," MSFC ASR-PD-D-72-2, March 1, 1972 (Ref 2). Because of the small size of the airlock, the unmodified platform with its group of experiments will not fit. However, individual ST-100 experiments can be accommodated by modifying the platform structure, relocating equipment, proper counterbalancing of the platform, and by minor modifications to the instruments. The modified configurations are shown in Figure IV-7. None of the other UV experiments defined in this study will fit into the airlock.

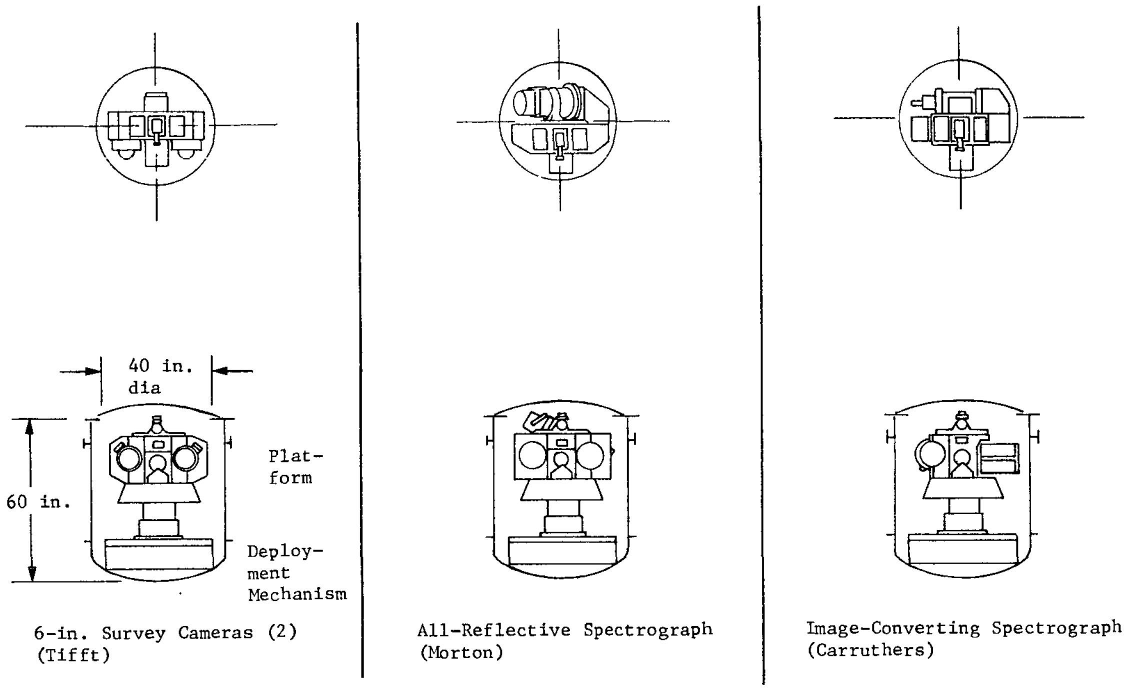

Figure IV-7 Modified ST-100 in Sortie Lab Airlock

Each of the UV experiment groups defined in this study can physically be accommodated on the modified ST-100 platform if not constrained within the airlock. Three configurations are shown in Figure IV-8.

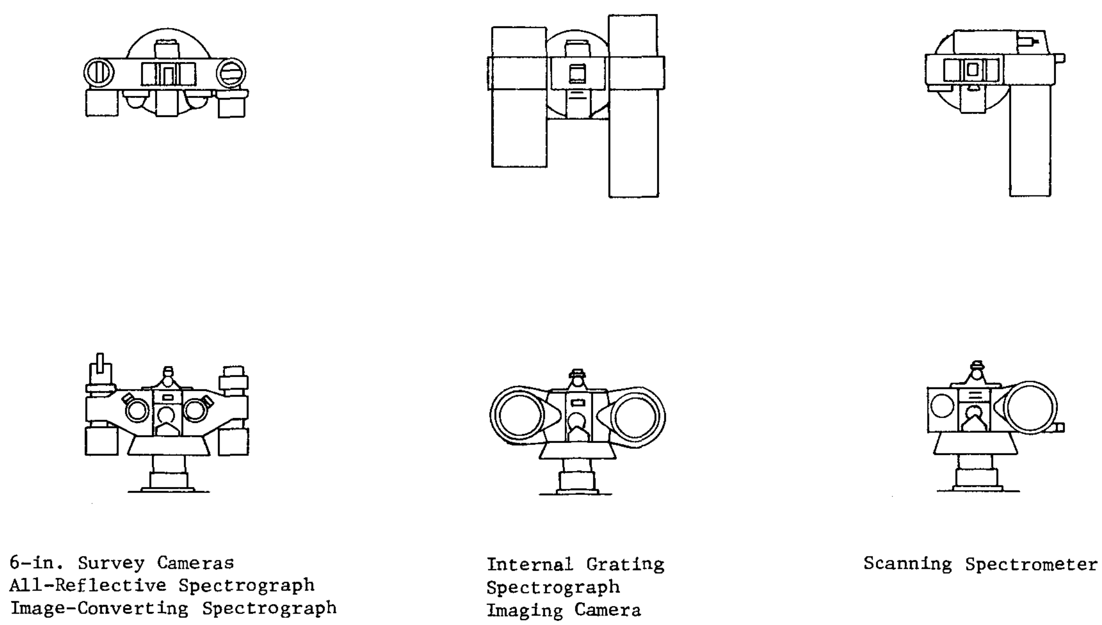

Figure IV-8 ST-100 Instrument Accommodation

In each case, except for the original ST-100 experiment complement, the platform structure must be modified and equipment relocated. Some of these modifications are unique to the experiments due to their shapes and sizes. The counterbalancing required in each case is unique. The ST-100 platform is shown in Figure IV-9 installed in the Shuttle payload bay on the pallet and without the pallet. It was assumed that sortie flights would generally have a pallet associated with the Sortie Lab. Experiments, such as biology, would not necessarily require a pallet, and the UV instrument platform would have to provide its own supporting structure to the Shuttle. In either case, the installations minimize physical interfaces with the Shuttle to facilitate fast turnaround. This is particularly important when flying the experiments on flights of opportunity. An outer gimbal platform (Fig. IV-10) could be installed in the Shuttle payload bay on the pallet and without the pallet, similar to the ST-100 platform installation.

b. Dedicated vs Flight of Opportunity - The platform and its instruments can benefit from the presence and dedicated participation of an astronomer only if: the results of the observations are available in near real time; the astronomer can dedicate a significant amount of his time to examining the results; and a meaningful reaction to those results can be taken. While all three of these conditions could be met, it seems very unlikely that any of them will be. To provide near-real-time results it would be necessary to remove the film frequently, have equipment for processing the film, and provide facilities for film inspection. This equipment is bulky, would consume valuable space in the Sortie Lab, and its use would preclude the possibility of general flights of opportunity, because even astronomical flights would not normally provide such facilities.

The astronomer will normally be heavily involved with the primary experiment or the larger telescopes that justify the flight and he cannot devote much time to the smaller UV survey instruments. Also, after the first few flights all the problems of exposure or other uncertainties and surprises will be worked out, so automated observations should be very reliable. It is possible that inspection of a new survey photograph would show that a program should be modified. It appears that there will be little requirement for an astronomer to be on board as far as the small UV telescopes are concerned. This could change if electronic sensors are used, or if a totally new instrument is being tried out that requires a great degree of attention.

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The advantage of a flight of opportunity is that small instruments could be flown more frequently, giving more scientists opportunities to try out ideas and instruments, and providing shorter lead time to useful data. However, many nonastronomical flights will be Earth oriented rather than inertially stabilized, so that the instrument platform must have a continuous slew of 4 degrees/minute. Even worse, the Shuttle bay will often be open toward the Earth, so that a boom must be used to get the platform out to the side where the stars can be seen. The Shuttle is stabilized to ±0.5 degrees with fairly high accelerations, and such a boom could be very difficult to use. For these reasons it may be that unrestricted flight-of-opportunity capability will not prove useful. The case for flights of opportunity on astronomical Sortie missions is much stronger. The Shuttle will be inertially stabilized, so that continuous slewing of the platform will not be required. The survey instruments may have film changes and some performance monitoring, however, because they could be designed for astronomical flights of opportunity, the operation would be mostly automatic.

Table IV-2 is a summary of the advantages and disadvantages for the dedicated mode and for the flight-of-opportunity mode.

Table IV-2 UV Instrument Mission Mode Implications

Program Considerations	Mission Mode	
	Flight of Opportunity	Dedicated Mission
Astronaut Participation	Minimum Interface Using Existing Experiment Concepts	Modify Concepts and Accommodation to Use Crew Skills
Support Hardware Requirements	Minimum Requirements Controls & Displays Provide Adequate Film for 7 days	Airlock Resupply Film On-Board Film Processing
Mission Parameters	Inertially Stabilized Spacecraft Inclination and Launch Window Constraints	Select Orbit Conditions for Desired Target Areas Optimize Dark Time
Operations	Automatic after Checkout and Deployment	Interrupt Data Taking to Change Film Process and Interpret Film
Scientific Objectives	Satisfactory	Satisfactory

c. Recommended Mission Mode - The flight-of-opportunity mode was selected, because the scientific objectives of the UV instruments can be satisfied with minimum crew and hardware interfaces, and the multiple missions necessary for complete survey of the celestial sphere can be flown.

5. Platform Stabilization and Control Analysis

Possible types and characteristics of stabilized platforms required for pointing and stabilization of the UV survey instruments were analyzed during the study. The pointing and stabilization requirements of the instruments were compared with the available performance data on the NASA/MSFC ST-100-SI Platform. Shortcomings of the ST-100 platform were discussed and necessary improvements were identified. An outer gimbal configuration for the platform was also considered.

For this analysis of stabilization and control, the items of particular interest concerning each instrument were:

1) Guiding (stabilization) accuracy requirement;

2) Pointing accuracy requirement;

3) Instrument field of view;

4) Instrument orientation requirements (location of sources of interest).

Other data values help to describe the instruments and to identify physical compatibility with the stabilizing platform. Examination of the data showed that some of the instruments are easier to accommodate than others. The instruments designed for rocket-flight interfaces generally do not require extreme stabilization accuracies. In contrast, instruments that were originally designed as balloon-borne payloads, are considerably more sophisticated and demanding.

a. ST-100 Platform - The ST-100-Stellar Instrument Platform was originally designed as a stabilized mount for three small UV survey instruments (boresighted on the platform) to be carried on an early Skylab flight. The mechanical design of the platform consists of a conventional internal gimbal system. Each gimbal axis includes two double-race ball-bearings, a brushless synchro resolver, and one or two brushless torquers (two torquers are used in the axis with high moment of inertia). The "inertial gimbal," or instrument mounting frame, must be specially tailored to optimize the physical mounting arrangement of the instruments assigned to a specific flight. It is possible to accurately balance the "inertial gimbal" with counterweights, so that the center of gravity of the assembly is located precisely at the point of intersection of the three gimbal axes. This provides for good decoupling of the instrument mounting frame from motions of the spacecraft; residual coupling can be attributed primarily to bearing stiction and rolling friction, and to cable bending friction. A conventional mechanical-contact caging mechanism is included to provide a rigid structural support during launch/reentry periods, and perhaps when high acceleration vehicle maneuvers are required.

To change the platform orientation, the synchro transmitters at the control panel are rotated to selected gimbal angles, which introduces a bias in the control loops. The platform slews until the commanded orientation is reached when the resolvers at the gimbals match the synchro transmitter settings. To hold the commanded position, a triad of mutually orthogonal floated rate integrating gyros is used, mounted (strapped down) on the "inertial gimbal." The output of each gyro is connected directly through an amplifier, shaping network, and a signal conversion module, to the corresponding brushless torquer. The nominal "crossover" point of the gimbal stabilization systems is estimated to be between 10 and 20 rad/sec^{-1} (closed loop response of about 1.6 to 3 Hz).

One aspect of the ST-100-SI design, of particular interest to the pointing control and stabilization area, involves the rate gyros. For the original design, the gyro triad used Kearfott "King" rate gyros, with a drift/bias rating of 9.4 deg/hr ($\sim$2 μrad/sec^{-1}) if uncompensated. By careful bias compensation, the drift rate can be reduced to 0.03 to 0.04 deg/hr ($\sim$0.15 to 0.20 μrad/sec^{-1}). These Kearfott units are small, dependable, high-output-level components, but they appear to be the major source of platform drift, limiting the guiding accuracy (stability) of the platform. The instrument payload that can be carried will depend on the moments of inertia of the "inertial gimbal" assembly, and on the torque delivered by the brushless torquers. The engineering model unit designed to carry the ST-100 instruments had the following characteristics:

1) $I_x = 529 \times 10^6$ g cm^2 = 39 slug ft^2; T_x = 7.3 N m = 5.4 lb ft;

2) $I_y = 390 \times 10^6$ g cm^2 = 29 slug ft^2; T_y = 4.9 N m = 3.6 lb ft;

3) $I_z = 84.5 \times 10^6$ g cm^2 = 6.2 slug ft^2; T_z = 2.4 N m = 1.8 lb ft.

Freedom in the roll axis (outer gimbal, x) is ±1.74 radians = ±100 degrees, and in the pitch (middle gimbal, y) and yaw (inner gimbal, z) it is ±0.26 radian = ±15 degrees. The nominal design performance characteristics of the ST-100-SI platform, as derived from the available documentation, and from personal discussions with NASA/MSFC personnel, are shown in Table IV-3.

To provide the platform characteristics required by the instruments (Table IV-1), the ST-100-SI platform requires some easily defined improvements. The most obvious step in upgrading the platform guiding error (stabilization accuracy) is to substitute the original type of rate gyros for some of the currently available units with improved drift rate performance specifications. Qualified units with nominal drift rate of 0.003 and 0.001 deg/hr can be substituted for the original units in the same mounting location, with only a slight increase in unit cost.

For stabilization in the range of 2 to 10 arc seconds (10 to 50 μrad) in the presence of the anticipated torques generated by the spacecraft motions and by the survey instruments during film change, it is generally necessary to resolve the gyro outputs through appropriate coordinate transformations. This would eliminate the undesirable cross-coupling effects between the gimbal axes that occur if the gimbals are not orthogonal. These coordinate transformation computations are easy to perform with simple, special-purpose mini-computer equipment. The frequency content of the anticipated input disturbance torques extends to at least 2 Hertz (12.5 rad/sec^{-1}), depending partly on the type of stabilization used in the spacecraft. To overcome these input disturbances to the required level of instrument stabilization, a closed-loop response of at least 5 Hertz (31.4 rad/sec^{-1}) will be necessary.

Torquer output capabilities may also require upgrading, particularly if more massive instruments, with awkward installation constraints, are considered. To achieve the capability to launch and retrieve the platform in any selected orientation relative to the spacecraft axes, it is necessary to use a later design of the platform that includes large bearings in the roll axis (outer gimbal, axis of wide freedom).

Table IV-3 ST-100-SI Platform Characteristics

	SI	English
Weight:		
Platform without Instruments	115 kg	250 lb
Control and Display Panel	34 kg	75 lb
Platform with Instruments and Interface Equipment	290 kg	635 lb
Instrument Payload Capacity	300 kg	440 lb
Dimensions, without Instruments:		
Height (x)	1.07 m	42 in.
Length (y)	1.27 m	50 in.
Width (z)	0.94 m	37 in.
Dimensions, with Instruments:		
Height (x)	1.27 m	50 in.
Length (y)	1.83 m	72 in.
Width (z)	1.0 m	39 in.
Angular freedoms:		
ϕ_x (roll)	±1.74 rad	±100 deg
θ_y (pitch)	±0.26 rad	± 15 deg
ψ_z (yaw)	±0.26 rad	± 15 deg
Pointing Accuracy (3 axes)	9 mrad	0.5 deg
Stability (guiding error):		
Short Term, rms	60 μ rad	12 $\widehat{sec}$
Long Term (over 20 min)	250 μ rad	50 $\widehat{sec}$
Stabilization System Closed-loop Bandwidth	10-20 rad sec^{-1}	1.6-3 Hz
Power Requirements:		
Peak (stalled at full power)	790 W	
Average (platform operating)	165 W	
Average over one Full Orbit	120	
Mounting Interface:		
Flat flange with 8 holes uniformly spaced in a circular pattern		
Flange Width	35 mm	1.375 in.
Flange Outer Diameter	406 mm	16 in.
Diameter of Hole Pattern Circle	381 mm	15 in.
Diameter of Mounting Screw Holes	9.5 mm	3/8 in.

There are two reasons why it was considered desirable to have Shuttle spacecraft orientation data from the IMU available at the platform operations control computer:

1) The crewman should be able to select exposure fields based on right ascension and declination (celestial) coordinates;

2) If spacecraft angular rate signals are available from the IMU, it is possible to use these signals in the platform stabilization loops to further reduce the effects of Shuttle motions during instrument data acquisition periods.

If these modifications and improvements are included, it appears that the ST-100-SI Platform can meet the pointing control and stabilization requirements for the small UV survey instruments.

Modifications and improvements that would significantly upgrade the ST-100 platform concept are listed in Table IV-4.

Table IV-4 ST-100 Platform Modifications/Improvements

Assembly/ Characteristic	Performance: ST-100	Performance: Modified/Improved	Comments
Rate Gyros- Drift Bias	0.4°/Hour (2×10^{-6} rad/sec)	0.001°/Hour (0.5×10^{-8} rad/sec)	Major source of platform drift. Qualified units with lower drift rate in same mounting location.
Closed-Loop Response	1.6 to 3.0 Hertz (10 to 20 rad/ sec)	5 Hertz (31.4 rad/sec)	Frequency content of Anticipated input disturbance torques extends to $\approx$ 2 Hz (function of S/C stabilization).
Torquers			Upgrade to support other large instruments with awkward installation constraints.
Pointing Accuracy	Platform Gimbal Angles to $\pm 90 \times 10^{-4}$ radians ($\pm 30 \widehat{\min}$)	Initial Orientation by Crewman. Pointing Changes Relative to Ouptut of Improved Rate Gyros.	Input to platform operations control computer to select exposure fields based on celestial coordinates.
Bearing			Incorporate larger roll axis bearings.

As shown, stabilization accuracy can be upgraded by substituting the original rate gyros with currently available units with improved drift rate performance specifications. Qualified units are available that can be substituted in the same mounting locations. The pointing control and stabilization loop should be extended to at least 5 Hertz to overcome the anticipated input torques. Initial pointing orientation will be performed by the crewman, and changes to other targets will be derived from the output data of the improved rate gyros. The output capabilities of the brushless torquers will require upgrading to accommodate the larger instruments. Larger roll axis bearings provide the capability to deploy and retrieve the platform in any selected orientation relative to the spacecraft axis.

b. Outer Gimbal Platform - The UV experiment groups identified earlier were examined to determine the smallest circular mounting platform capable of mounting any of the groups (Fig. IV-11).

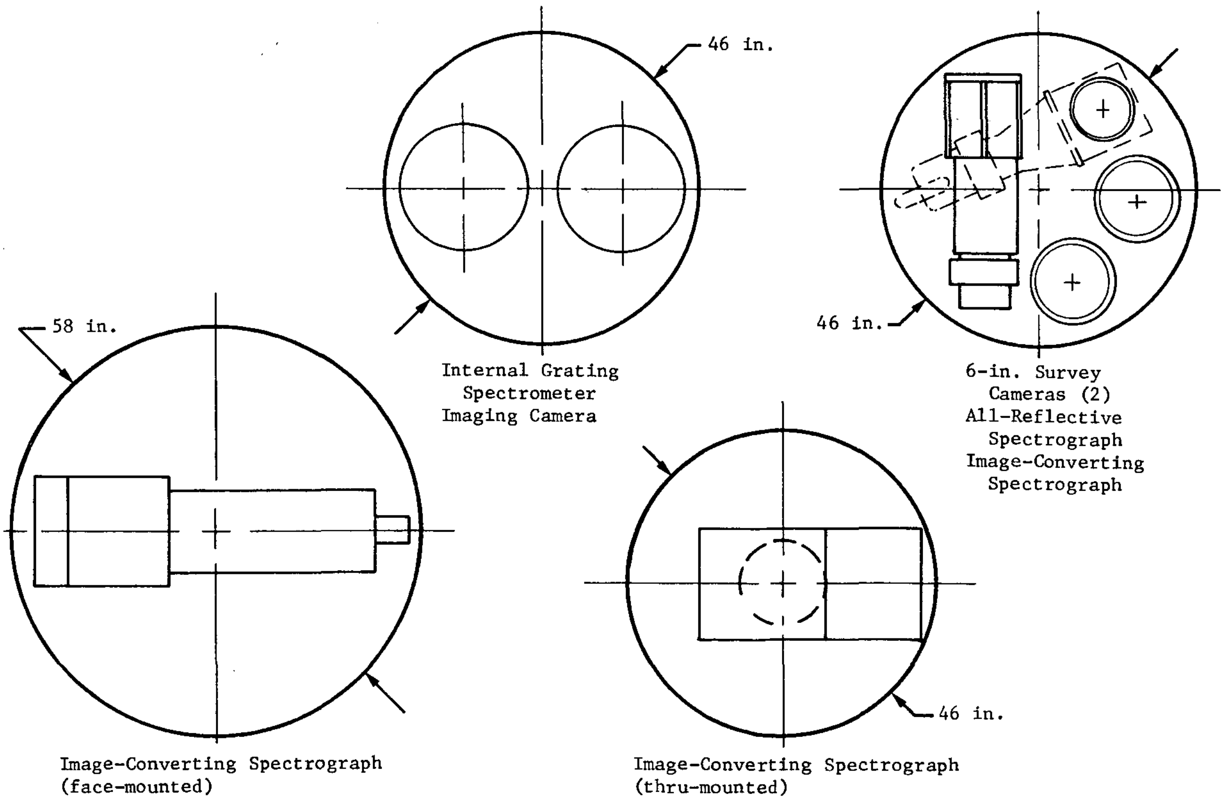

Figure IV-11 UV Outer Gimbal Platform Sizing Study

The size of the circle shown in the figure represents the inside diameter of the inner roll ring of a conventional three-axis outer gimbal system. All of the experiment groups fitted readily on a 117-centimeter (46-in.) diameter platform, except for the ST-100 group and the Image-Converting Spectrograph. By mounting one of the instruments on the far side of the platform and providing a viewing hole in the platform, the ST-100 group could be mounted on the platform. The Image-Converting Spectrograph could not be face-mounted on the platform, but can be through-mounted as shown. The outer gimbal system is similar to the 213-centimeter (84-in.) system recommended in the earlier part of the study to accommodate the intermediate class instrument. This system uses an azimuth table that provides complete 360-degree rotation, plus an elevation mechanism that gives a gimbal range of ±90 degrees. This azimuth-elevation system can achieve hemispherical coverage without requiring that the instruments and platform be deployed out of the cargo bay. The platform capabilities derived to satisfy the wide field-of-view UV survey instruments are listed in Table IV-5. Weights for the outer gimbal platform installation, with and without pallet, are given in Table IV-6.

Table IV-5 UV Platform Capabilities

Pointing Accuracy	5.8×10^{-4} radian (2 $\widehat{\text{min}}$)
Stability	5×10^{-6} radian (1 $\widehat{\text{sec}}$)
Stabilization System Closed-Loop Bandwidth	31.4 rad/sec (5 Hz)
Gimbal Travel	Hemispherical
Weight of Experiments	200 kg (440 lb)

c. Recommended Platform - The outer gimbal mount configuration is recommended as the platform to accommodate the UV instruments. One of the factors considered was that several of the instruments analyzed in this study may undergo significant changes during development efforts. Since the ST-100 platform was configured for specific small experiments, its capabilities and versatility are limited. Modifications of the ST-100 platform are necessary to meet the requirements of the UV instrument groups that were studied. In addition, the internal gimbal arrangement is difficult to counterbalance when the experiment complement is unsymmetrical. Another important factor is that hemispherical viewing capabilities of the outer gimbal concept enhance the operation of the telescopes on flights of opportunity. While higher weight and cost may be unavoidable, the advantages of the outer gimbal mount configuration outweigh the disadvantages.

Table IV-6 UV Outer Gimbal Platform Installation Weights

	SI, kg		English, lb	
Gimbal System				
Gimbal Rings		123.2		272
Roll Drive		5.0		11
AZ Stabilization Actuator		18.2		40
EL and Pointing Stabilization Actuator		31.8		70
AZ Yoke and Table		94.3		208
AZ Drive		9.1		20
Launch Locks		29.5		65
Equipment Platform		4.5		10
Support Equipment		31.8		70
Eject Mechanism		23.1		51
Miscellaneous and Cabling		10.4		23
		381.0		840
With Pallet				
Gimbal System	381		840	
Truss	33.2		71	
		414.2		911
Without Pallet				
Gimbal System	381		840	
Truss	67.2		148	
		448.2		988

6. Support Requirements

a. Interfaces - The range of accommodation requirements for the small UV astronomy payloads is shown in Table IV-7 for the proposed flight of opportunity mission mode. These requirements include the platform outer gimbal mount and truss supports, pointing and control components, and the additional instrument support hardware, except for the remote controls and displays (remote controls and displays add 44 Watts, 16.3 kilograms (36 lb), and 0.2 kbps to the respective requirements).

Table IV-7 UV Instrument Accommodation Requirements

Parameter	Minimum	Maximum
Size, Cargo Bay Length - Meters (in.)	≈2.54 (100)	≈2.54 (100)
Weight - kg (lb)	468 (1031)	633 (1396)
Data - kbps	1.0	21.0
Power - Watts	330	465
Pointing Accuracy - Radians ($\widehat{\text{min}}$)	29×10^{-4} (10)	5.8×10^{-4} (2)
Pointing Stability - Radians ($\widehat{\text{sec}}$)	58×10^{-6} (12)	5×10^{-6} (1)

The maximum weight requirement reflects a UV instrument platform mounted with a drop truss structure in lieu of having a Shuttle pallet available. Maximum payload weight was developed using the ST-100 grouping payload weight of 176 kilograms (389 lb), the drop truss structure weight of 450 kilograms (988 lb), plus experiment support equipment weight of 8.6 kilograms (19 lb). Maximum power was derived by adding the ST-100 grouping power requirement of 151 Watts to the experiment support equipment power requirement of 314 Watts. The maximum data rate of 20 kbps was generated specifically from the proposed Scanning Spectrometer (Kondo) experiment. Pointing accuracy and stability must be provided by the proposed outer gimbal mount and platform.

b. Hardware - The hardware recommended to support the small UV instruments for flights of opportunity (Table IV-8) consists of the platform with gimbals, the mount, the gyro package, electronics and experiment support equipment, and the payload controls and displays.

The platform consists of an outer gimbal system similar to the system recommended for the intermediate class instruments. The mount is capable of ±180-degree azimuth and 90-degree elevation travel to provide hemispherical coverage independent of spacecraft attitude. Rate gyros with drift rates of 0.5×10^{-8} radians/second (0.001 deg/hr) are incorporated to hold the initial commanded position and to provide reference outputs for automatic programming to preselected targets. The control system provides a closed-loop response of at least 5 Hertz (31.4 rad/sec) to overcome disturbances from anticipated torques.

Table IV-8 UV Instrument Support Hardware

Platform (gimbals have ±2.5-deg stabilization travel)
Pointing Accuracy: 5.8×10^{-4} radian (2 $\widehat{\text{min}}$)
Pointing Stability: 5.0×10^{-6} radian (1 $\widehat{\text{sec}}$)
Mount - Azimuth and Elevation
Travel: Hemispherical Coverage
Gyro Package
Drift: 0.5×10^{-8} rad/sec (0.001 deg/hr)
Electronics
Distribution Boxes (Power and Telemetry)
Programmer (Experiment Control and Sequencing)
Mini-Computer
Experiment Support
Vidicon Camera (Star Field Observation)
Reference Camera
Sun-Earth Sensor
Radiation Detector (SAA and Lyman-Alpha)
Controls and Displays
Platform and Gimbal Functions
Experiment Support

Electronics and experiment support equipment mounted on the platform provides power, control, and status monitoring of the support hardware and the UV instruments. The mini-computer is used to perform the coordinate transformation computations for platform pointing and to allow target programming based on celestial coordinates, not on platform gimbal angles as is the case in the ST-100 platform designs. A closed-circuit TV system is provided for crewman confirmation that the platform is on target before beginning an experiment exposure sequence. The reference camera takes one exposure for each exposure cycle of the UV instruments to assist in identifying the field of view. A sun-Earth sensor detects the presence of the sun or bright Earth within 30 degrees of the instrument look angle. Local flux monitors are used to program exposure duration and to indicate amount and time of possible data degradation. Functions and displays provided to the crewmen include the platform and mount controls, experiment and support equipment controls, TV monitoring system, and status indicators.

B. NONDEPLOYED SOLAR PAYLOAD

The objective of this task was to evaluate alternative methods of satisfying the solar payload viewing requirements. The concept recommended during the original 9-month Astronomy Sortie Mission Definition Study required that the entire solar payload be rotated through 90 degrees, so that the Sortie Lab's longitudinal axis was perpendicular to the Shuttle's longitudinal axis. The ground rule for the original study was that the deployment mechanism was charged to the Shuttle orbiter. At the final performance review, personnel from the Sortie Lab project at MSFC requested that the solar payload concept be re-examined, since the latest Shuttle ground rule had the deployment mechanism charged to the payloads. As a result of this task, the configuration now recommended for the solar payload is a nondeployed concept that does not require the deployment mechanism.

1. Ground Rules and Assumptions

The ground rules and assumptions that were used during the performance of this task are:

1) The deployment mechanism shall be charged to the payload - revised study ground rule;

2) The deployment mechanism shall be as defined by the GDC document Shuttle/RAM Deployment Mechanism Conceptual Design (Ref 6). The deployment mechanism weight is 900 kilograms (2000 lb) and length is 1.52 meters (5 ft);

3) Deployed payloads shall not exceed 13.72 meters (45 ft) in length - extracted from Sortie Lab Design Requirements (Ref 7);

4) A deployable pallet 9.75 meters (32 ft) in length weighs 544 kilograms (1200 lb) more than a nondeployable pallet - extracted from Sortie Lab Briefing to Solar Physics Working Group (Ref 8).

2. Alternative Configurations

Four solar payload configurations were evaluated. They consisted of the baseline deployed configuration defined during the original 9-month study, a modified baseline, and two nondeployed configurations. Three different inertial attitudes also considered in the analyses were: X-POP (Shuttle's longitudinal axis perpendicular to the orbit plane); X-IOP (Shuttle's longitudinal axis in the orbit plane); and Z-POP (Shuttle's longitudinal axis in the orbit plane and the Z axis perpendicular to the orbit plane).

The four configurations were evaluated in terms of total weight and length, compatibility with stellar payloads, momentum requirements for the various inertial attitudes, compatibility with the revised ground rules, and viewing capabilities of the solar instruments.

a. Baseline Configuration - The baseline configuration recommended at the completion of the original 9-month study is shown in Figure IV-12. The significant characteristics of this configuration are: the entire payload must be deployed from the Shuttle cargo bay to enable the solar instruments to view the sun; the Shuttle maintains an X-POP inertial attitude throughout the 7-day mission; the deployment mechanism is charged to the Shuttle orbiter; the orbit inclination is greater than 67 degrees to enable continuous sun viewing during the 7-day mission; and the ancillary hardware is common with the stellar payloads. A detailed description of the baseline configuration is presented in Volume III, Book 1 of the original 9-month study Final Report (Ref 1).

The weight statement for this configuration is summarized in Table IV-9. The total payload weight of 13,067.5 kilograms (28,809 lb) is based on the use of three ATM-type control moment gyros (CMG) to stabilize the entire Shuttle in an X-POP inertial attitude. The weight also includes the use of a 4.73-meter (15.5-ft) Sortie Lab that weighs 5755.1 kilograms (12,688 lb) and a standard pallet that weighs 1388 kilograms (3060 lb). The total payload length is 17.83 meters (58.5 ft), exclusive of the deployment mechanism.

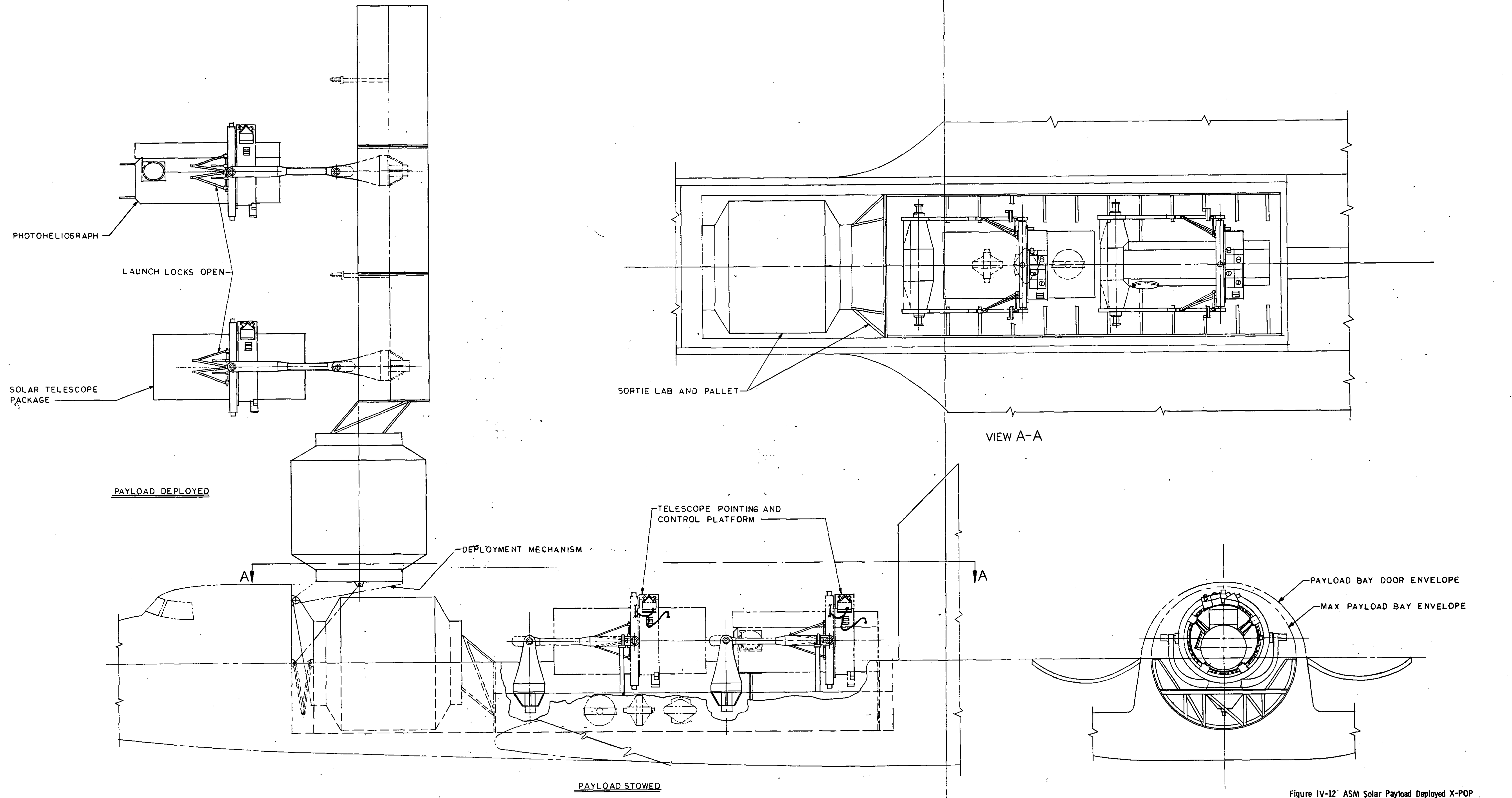

Figure IV-12 ASM Solar Payload Deployed X-POP

IV-37 and IV-38

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-9 Baseline Configuration Weights [kg (lb)]

Sortie Lab - 4.73 meters (15.5 ft)		5,755.1 (12,688)
Pallet - 13.2 meters (43 ft)		1,388.0 (3,060)
Stabilization System		713.5 (1,573)
CMG (3)	571.5 (1260)	
CMG Inverter (3)	77.6 (171)	
IMU	6.8 (15)	
Control and Input Box	9.1 (20)	
Supports and Cabling	48.5 (107)	
Mount and Gimbal Systems		2,143.7 (4,726)
Forward Common Mount	481.7 (1062)	
Aft Common Mount	481.7 (1062)	
Ordnance	9.1 (20)	
Forward Gimbal System	585.6 (1291)	
Aft Gimbal System	585.6 (1291)	
Electrical and Data System		43.1 (95)
Thermal Insulation		59.0 (130)
Solar Instruments		2,965.1 (6,537)
Photoheliograph	997.9 (2200)	
Solar Group	1967.2 (4337)	
Total Payload		13,067.5 (28,809)

The primary advantages of this configuration, and the reasons it was selected as the baseline for the original 9-month study are:

1) The Shuttle could be maintained in an X-POP inertial attitude, which is the best inertial attitude in terms of momentum requirements;

2) The ancillary hardware (i.e., mounts, stabilization system, etc) is common with the stellar payloads;

3) The deployment of the entire payload minimizes any viewing constraints on the instruments due to reflecting surfaces in the field of view of the instruments;

4) The configuration was compatible with the study ground rule that charged the deployment mechanism weight and volume to the Shuttle orbiter.

b. Modified Baseline Configuration - One alternative that was evaluated for possible use was a modified baseline configuration. This configuration (Fig. IV-13) was developed in an effort to be compatible with the modified study ground rules. To provide volume in the Shuttle cargo bay for the hinged deployment mechanism it was necessary to shorten the overall length of the payload by 1.52 meters (5 ft). This was accomplished by relocating the forward mount closer to the aft end of the Sortie Lab. This modification results in a limited capability azimuth table that is acceptable for the solar payloads, but not for the stellar. In addition, it was also necessary to reverse the positions of the photoheliograph and solar group telescopes in order to reduce the overall length.

The totel payload weight for this configuration is 13,702.9 kilograms (30,209 lb) (Table IV-10).

Table IV-10 Modified Baseline Configuration Weights [*kg (lb)*]

Sortie Lab - 4.73 meters (15.5 ft)		5,755.1 (12,688)
Pallet - 12.05 meters (39.5 ft)		1,115.8 (2,460)
Deployment Mechanism		907.2 (2,000)
Stabilization System		713.5 (1,573)
CMG (3)	571.5 (1260)	
CMG Inverter (3)	77.6 (171)	
IMU	6.8 (15)	
Control and Input Box	9.1 (20)	
Supports and Cabling	48.5 (107)	
Mount and Gimbal Systems		2,143.7 (4,726)
Forward Common Mount	481.7 (1062)	
Aft Common Mount	481.7 (1062)	
Ordnance	9.1 (20)	
Forward Gimbal System	585.6 (1291)	
Aft Gimbal System	585.6 (1291)	
Electrical and Data System		43.1 (95)
Thermal Insulation		59.0 (130)
Solar Instruments		2,965.1 (6,537)
Photoheliograph	997.9 (2200)	
Solar Group	1967.2 (4337)	
Total Payload		13,702.9 (30,209)

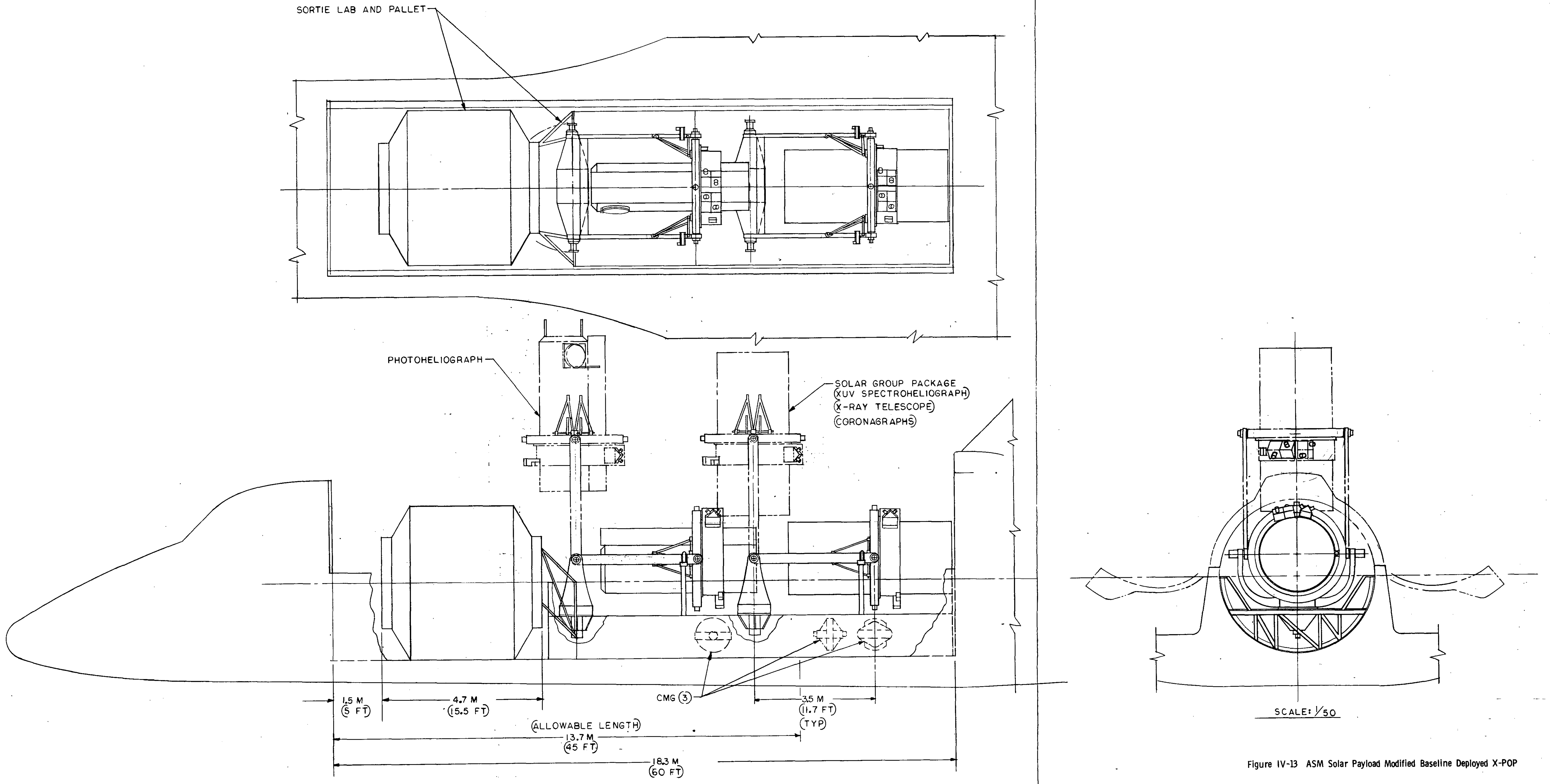

Figure IV-13 ASM Solar Payload Modified Baseline Deployed X-POP

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

This weight is based on the use of three ATM-type CMGs to stabilize the entire Shuttle in an X-POP inertial attitude, a Sortie Lab weight of 5755 kilograms (12,688 lb), a pallet weight of 1115.8 kilograms (2460 lb) and a deployment mechanism weight of 907.2 kilograms (2000 lb). The total payload length is 16.77 meters (55 ft), exclusive of the deployment mechanism, which requires an additional 1.52 meters (5 ft).

Although it was possible to modify the baseline configuration to allow an additional 1.52 meters (5 ft) for the deployment mechanism, it was not possible to shorten the payload to the 13.72-meter (45-ft) length that is required for deployable payloads. Therefore, this configuration was dropped from any future consideration since it did violate the new study ground rules.

c. Nondeployed X-POP Configuration - As an alternative to deploying the entire payload out of the cargo bay, a canted configuration was investigated. This canted configuration (Fig. IV-14) is significant in that: payload deployment is not required; the Shuttle can maintain an X-POP inertial attitude; the solar instruments are deployed from the cargo bay at offset angles that allow both sets of instruments to view the sun; and the ancillary hardware is compatible with the stellar payloads.

The characteristics of this configuration are compatible with the modified study ground rules, since the entire payload does not require deployment. However, the major disadvantage of this configuration is the need for the solar instruments to view across the top of the Shuttle cabin. Although the instrument fields of view clear the Shuttle, reflections from the Shuttle surfaces could still be detrimental. This is especially true of the Coronagraphs, which will view as far out as 30 solar radii. At this distance the source signal will be relatively weak and reflections off the Shuttle could be a significant problem. Special coating or baffles on the Shuttle or solar instruments may adequately suppress the reflections, but could be impractical or costly to implement.

The detailed weight statement for this configuration is shown in Table IV-11. The total payload weight is 12,227 kilograms (26,956 lb) and includes: the 4.73-meter (15.5-ft) Sortie Lab that weighs 5755.1 kilograms (12,688 lb); a lightweight pallet that is nondeployable and is 13.6 meters (44.5 ft) in length and weighs 502.1 kilograms (1107 lb); and three ATM type CMGs that will stabilize the entire Shuttle in an X-POP inertial attitude throughout the 7-day sortie mission.

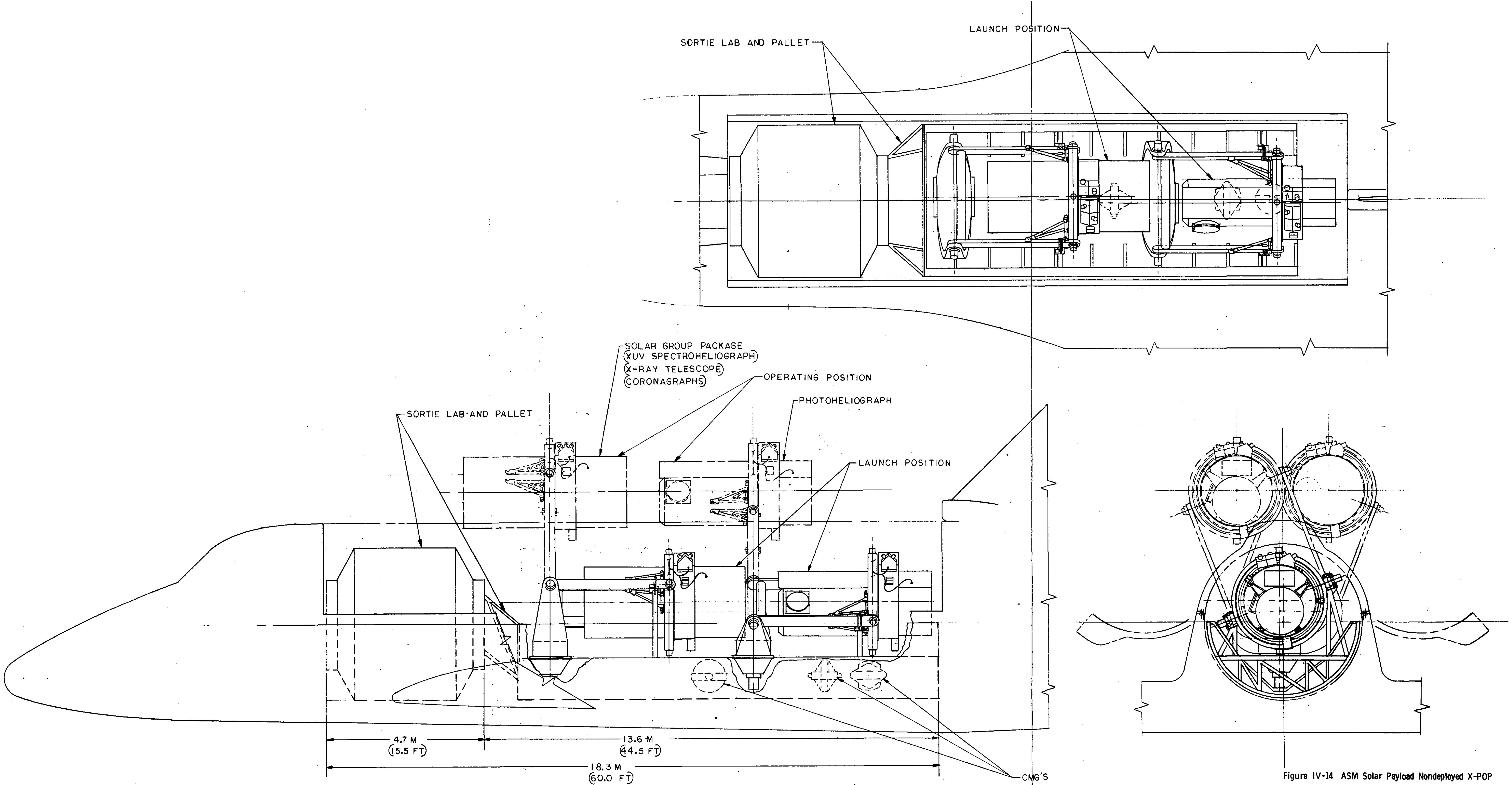

Figure IV-14 ASM Solar Payload Nondeployed X-POP

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

Table IV-11 Nondeployed X-POP Configuration Weights [*kg (lb)*]

Sortie Lab - 4.73 meters (15.5 ft)		5,755.1 (12,688)
Pallet - 13.6 meters (44.5 ft)		502.1 (1,107)
Stabilization System		713.5 (1,573)
CMG (3)	571.5 (1260)	
CMG Inverter (3)	77.6 (171)	
IMU	6.8 (15)	
Control and Input Box	9.1 (20)	
Supports and Cabling	48.5 (107)	
Mount and Gimbal Systems		2,189.1 (4,826)
Forward Common Mount	509.4 (1112)	
Aft Common Mount	509.4 (1112)	
Ordnance	9.1 (20)	
Forward Gimbal System	585.6 (1291)	
Aft Gimbal System	585.6 (1291)	
Electrical and Data System		43.1 (95)
Thermal Insulation		59.0 (130)
Solar Instruments		2,965.1 (6,537)
Photoheliograph	997.0 (2200)	
Solar Group	1967.2 (4337)	
Total Payload		12,227.0 (26,956)

d. Nondeployed X-IOP or Z-POP Configuration - The final concept investigated was the nondeployed X-IOP or Z-POP configuration. This configuration (Fig. IV-15) is essentially the same as the baseline configuration but without the payload deployment requirement. Because the payload is not deployed, it is not possible to maintain an X-POP inertial attitude with the Shuttle, and consequently two other inertial attitudes were considered, they were the X-IOP (Shuttle's longitudinal axis in the orbit plane) and the Z-POP (Shuttle's longitudinal axis in the orbit plane and its Z axis perpendicular to the orbit plane). Each of these inertial attitudes require the addition of one ATM type CMG to counteract the gravity gradient torques.

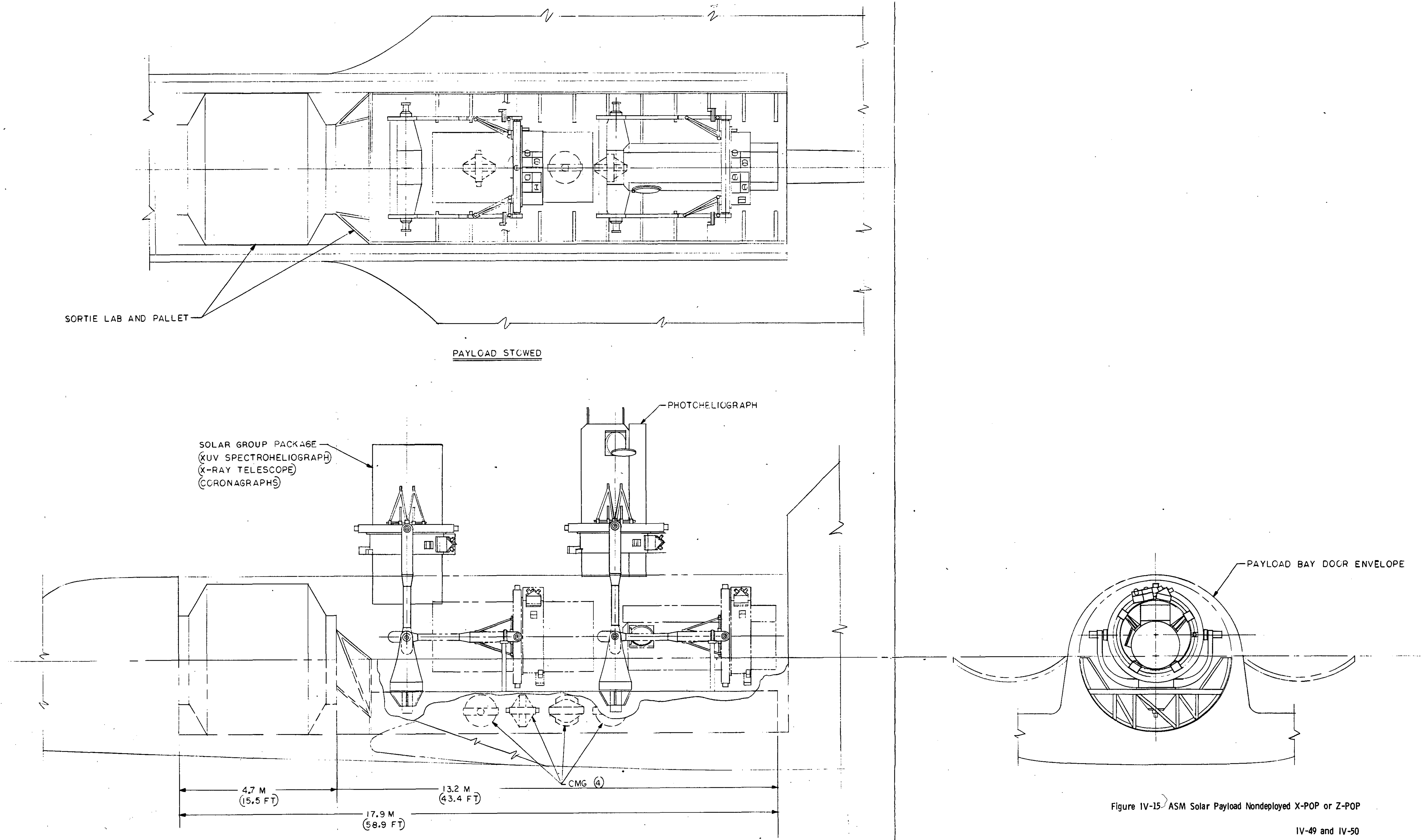

Figure IV-15 ASM Solar Payload Nondeployed X-POP or Z-POP

FOLDOUT FRAME 1

FOLDOUT FRAME 2

The characteristics of this configuration are: (1) payload deployment is not required, (2) the Shuttle inertial attitude must be X-IOP or Z-POP, (3) the ancillary hardware is common with the stellar payloads, and (4) four ATM type CMGs are required to maintain the Shuttle in an X-IOP or Z-POP inertial attitude during the 7-day mission.

The detailed weight statement for this configuration is presented in Table IV-12.

Table IV-12 Nondeployed X-IOP or Z-POP Configuration Weights [kg (lb)]

Sortie Lab - 4.73 meters (15.5 ft)		5,755.1 (12,688)
Pallet - 13.2 meters (43.4 ft)		502.1 (1,107)
Stabilization System		946.2 (2,086)
CMGs (4)	762.0 (1680)	
CMG Inverter (4)	103.4 (228)	
IMU	6.8 (15)	
Control and Input Box	10.0 (22)	
Supports and Cabling	63.9 (141)	
Mount and Gimbal Systems		2,143.7 (4,726)
Forward Common Mount	481.7 (1062)	
Aft Common Mount	481.7 (1062)	
Ordnance Package	9.1 (20)	
Forward Gimbal System	585.6 (1291)	
Aft Gimbal System	585.6 (1291)	
Electrical and Data System		43.1 (95)
Thermal Insulation		59.0 (130)
Solar Instruments		2,965.1 (6,537)
Photoheliograph	997.9 (2200)	
Solar Group	1967.2 (4337)	
Total Payload		12,414.3 (27,369)

The total payload weight of 12,414.3 kilograms (27,369 lb) includes: the 4.73-meter (15.5-ft) Sortie Lab weight of 5755.1 kilograms (12,688 lb); a lightweight nondeployable pallet 13.2 meters (43.4 ft) in length and weighing 502.1 kilograms (1107 lb), and a stabilization system that has four CMGs.

This was the configuration that was selected as the preferred solar payload concept as a result of analyses performed during this task.

3. Inertial Attitudes

Because the inertial attitude of the Shuttle orbiter has a major impact on the configuration of the solar payload, three different inertial attitudes were investigated--X-POP, X-IOP, and Z-POP. Each of these inertial attitudes places different requirements on the number of CMGs that are necessary to stabilize the Shuttle, and on the deployment and gimbal mechanisms that are required for solar viewing.

The four configuration alternatives considered the differences in the deployment and gimbal mechanisms that would be necessary to view the sun for the indicated inertial attitudes. This section of the report summarizes the analyses performed to determine the requirements and tradeoffs for pointing and control of the Shuttle orbiter. Calculations were made to determine the momentum resource requirements, electrical power requirements, numbers and weights of the CMG system, and size and weights of alternative reaction control systems (RCS). Although the original 9-month study did recommend the use of CMGs to stabilize the Shuttle orbiter, there is still sufficient interest in the use of an RCS to perform this function that it was desirable to show what the requirements would be for an RCS.

a. Assumptions - The Shuttle orbiter model used in this report assumed the following moments of inertia and products of inertia:

$I_x = 1.11 \times 10^6$ kg-m^2 (0.821×10^6 slug-ft^2)

$I_y = 9.66 \times 10^6$ kg-m^2 (7.130×10^6 slug-ft^2)

$I_z = 10.00 \times 10^6$ kg-m^2 (7.376×10^6 slug-ft^2)

$I_{xy} = I_{xz} = I_{yz} = 0.$

The Shuttle orbiter was assumed to be stabilized in a 270-nautical-mile circular orbit.

Sizing of the CMG system was performed according to the following ground rules. The momentum requirements for stability were computed for the contingency that gravity-gradient bias and cyclic torques may result from an axis misalignment of as much as 1 degree. For sizing, it was further assumed that momentum accumulations would be desaturated once every orbit rather than twice per orbit, in order to obviate potential interference with scientific observations. The momentum requirements for maneuvering were computed to obtain at least 2 degrees/minute about the axis of greatest inertia, giving much greater maneuver capability about the X-axis. The transition from attitude control propulsion system (ACPS) control to CMG control requires sufficient CMG momentum capability to absorb the maximum angular excursions possible when the ACPS control is terminated. Here, the assumption is made that immediately after transition to CMG control, the accumulated CMG momentum is removed by pulsing the ACPS in proper direction.

The CMG system was sized to handle the greater of these three requirements; one additional CMG was added for contingencies such as failure or the situation where a maximum effort maneuver is desired when accumulated momentum is near maximum. An important feature is that even with one CMG inoperative, sufficient capability will exist in each case to complete the scientific program with perhaps somewhat reduced maneuvering capability.

The momentum requirements computed for RCS control apply for a 7-day mission, and were computed on the basis of the same ground rules for stability, transition, and maneuvering as those used for CMGs. However, there are some differences in the way they must be applied. For the RCS, the requirements for stability, transition, and maneuvering are additive, as the momentum expended cannot be recovered. No additional fuel for other contingencies is carried, as the worst effect of running out of RCS fuel would be that the observation program would have to be terminated early. Because the location of the RCS thrusters on the Shuttle orbiter are not known, calculations of impulse were made using an average moment-arm of 35 feet for torquing the vehicle about all axes.

The momentum required for transition from the orbiter's ACPS to the CMG or RCS is based on the following orbiter rates:

ω_x = 3.470 mrad/sec (0.200 deg/sec);

ω_y = 0.400 mrad/sec (0.023 deg/sec);

ω_z = 0.387 mrad/sec (0.022 deg/sec).

b. Control Requirements for X-IOP Inertial Attitude - This section discusses the control requirements for a Shuttle orbiter inertially stabilized in an X-IOP orientation, using a CMG system or an RCS.

1) <u>CMG Momentum Requirements</u> - The Shuttle orbiter external torque environment is assumed to be primarily gravity-gradient induced torques with aerodynamic induced torques contributing only slightly. The proposed CMG system must be capable of maneuvering and stabilizing the vehicle. Considering the stabilization aspects, the CMG system must be capable of storing the total resultant gravity-gradient induced angular momentum, $H_{CMG}^{(STAB)}$, which is composed of an accumulated momentum component, H_a, due to constant axial torques, and a cyclic momentum component, H_c, which varies periodically, depending specifically on twice the Shuttle's orbital frequency, $2\omega_o$. The CMG gravity-gradient momentum storage requirement is maximized by using the peak cyclic momentum, $|H_c|$ peak, and is given by

$$H_{CMG}^{(STAB)} = |\vec{H}_a| + |\vec{H}_c|_p .$$

These values were computed using the following assumptions:

1) The Shuttle orbiter is in the X-IOP attitude and is initially oriented with its X and Y axes in the orbital plane;

2) The Shuttle orbiter is inertially held in its desired orientation throughout a complete orbit.

The magnitude of the accumulated momentum, $|\vec{H}_a|$, for a complete orbit, and the magnitude of the peak cyclic momentum components are found to be:

$$|\vec{H}_a|_x = 1740 \text{ N-m-sec (1280 ft-lb-sec)}$$

$$|\vec{H}_a|_y = 0$$

$$|\vec{H}_a|_z = 0$$

$$|\vec{H}_{cx}|_p = 0$$

$$\left|\vec{H}_{cy}\right|_p = 5050 \text{ N-m-sec } (3730 \text{ ft-lb-sec})$$

$$\left|\vec{H}_{cz}\right|_p = 5100 \text{ N-m-sec } (3760 \text{ ft-lb-sec}).$$

The total peak cyclic momentum is determined by

$$\left|\vec{H}_{c}\right|_p = \left[\left|\vec{H}_{cy}\right|_p^2 + \left|\vec{H}_{cz}\right|_p^2\right]^{\frac{1}{2}}$$

$$\left|\vec{H}_{c}\right|_p = 7180 \text{ N-m-sec } (5300 \text{ ft-lb-sec}).$$

The total CMG gravity-gradient momentum storage requirement for stabilization is therefore

$$H_{CMG}^{(STAB)} = \left|\vec{H}_a\right| + \left|\vec{H}_c\right|_p$$

$$= 8920 \text{ N-m-sec } (6580 \text{ ft-lb-sec}).$$

These magnitudes are computed for the case where $H_{CMG}^{(STAB)}$ has its maximum value obtained when the angle λ, which subtends the orbiter's Z-axis and its projection onto the orbital plane, has a value of λ = 44.8 degrees.

The angle, λ, can vary between 0 and 90 degrees while the vehicle remains in the X-IOP attitude. This will occur during stellar observations in order to point the instrument at various targets and will occur during solar observations because of variations in the Beta angle and regression of the orbit. Because of these potential variations for the angle, λ, two special cases have been computed--one for the λ = 90 degrees (Z-POP, X-IOP) attitude and one for the λ = 0 degree, resulting in a Y-POP, X-IOP attitude. These represent the extreme cases away from the maximum momentum requirements.

First, consider the (Z-POP, X-IOP) attitude where λ = 90 degrees. In this case, both the X and Y axes are in the orbital plane, an ideal condition that results in zero accumulated momentum. In addition, the peak cyclic X and Y momentum components H_{cx}, and H_{cy} are also zero. The only term that contributes to $H_{CMG}^{(STAB)}$ is

$$H_{cz} = 7050 \text{ N-m-sec } (5200 \text{ ft-lb-sec}).$$

Also, consider the (Y-POP, X-IOP) attitude for this orbit. In this case, both the X and Z axes are in the orbital plane, and λ = 0 degrees, a condition that also results in zero accumulated momentum. For this attitude, the peak cyclic X and Z momentum components H_{cx} and H_{cz} are zero. The only term contributing to $H_{CMG}^{(STAB)}$ is H_{cy} = 7340 N-m-sec (5420 ft-lb-sec).

These results (Table IV-13) show that the accumulated momentum H_a, is zero for both the (Z-POP, X-IOP) attitude and the (Y-POP, X-IOP) attitude. The (Z-POP, X-IOP) attitude also shows a lower total peak cyclic momentum requirement than the (Y-POP, X-IOP) attitude (by approx 4%).

As previously stated, the X-IOP attitude, which exhibits the greatest total stabilization momentum requirements, occurs for λ = 44.8 degrees. This attitude also develops the largest accumulated momentum per orbit and, therefore, requires desaturation. Table IV-13 contains two values for each component of the X-IOP, λ = 44.8-degree case. The smaller value is for an experimental period of approximately 66% of an orbit, while the larger value is for the total orbital period.

The table also shows that three ATM-type CMGs are sufficient to meet X-IOP stabilization requirements, in the absence of a maneuvering requirement.

In addition to stabilization requirements, the angular momentum capability for maneuvering must also be available at any time. To compute the CMG maneuvering capability requirements, the following assumptions are made:

1) Pointing the telescope to various targets is accomplished by two distinct Shuttle orbiter maneuvers--first, a maneuver about its Z-axis, and then one about its X-axis;

2) These maneuvers are performed at a maneuver rate of 2 degrees per minute.

Calculations show that for a maneuver rate of 2 degrees/minute, the X-axis and Z-axis angular momentums that must be imparted to the orbiter by the CMGs are:

$H_x^{(m)}$ = 646 N-m-sec (477 ft-lb-sec);

$H_z^{(m)}$ = 5820 N-m-sec (4300 ft-lb-sec).

The proposed orbiter CMG system must be sized so that its momentum maneuver capability $H_{CMG}^{(m)}$ equals H_z, the largest of the above momentums. Therefore, $H_{CMG}^{(m)}$ = 5820 N-m-sec (4300 ft-lb-sec) if the maneuver rate is to be 2 degrees/minute. This momentum capacity could be provided by two Skylab ATM-type CMGs.

Table IV-13 Stabilization Momentum Requirements, X-IOP

Inertial Attitude	Total Accumulated per Orbit N-m-sec (ft-lb-sec) $\lvert\vec{H}_a\rvert$	Peak Cyclic Momentum Components N-m-sec (ft-lb-sec) H_{cx}	H_{cy}	H_{cz}	Total Peak Cyclic Momentum N-m-sec (ft-lb-sec) $\lvert H_c\rvert_p = \left[\Sigma H^2_{ci}\right]^{1/2}_p$	Total Stabilization Requirements N-m-sec (ft-lb-sec) $H^{(STAB)}_{CMG} = \lvert\vec{H}_a\rvert + \lvert\vec{H}_c\rvert_p$	Number of ATM CMGs Required for $H^{(STAB)}_{CMG}$ Only
(Z-POP, X-IOP) $\lambda = 90$	0 0	0 0	0 0	7050 (5200)	7050 (5200)	7050 (5200)	2.3
(Z-POP, X-IOP) 1° Error about X and 1° Error about Y	1600 (1181) Total orbit	4.82 (3.55)	127.0 (94.0)	7050 (5200)	(7050 (5200)	8650 (6381)	2.8
X-IOP $\lambda = 44.8°$	1070 (792) (Exp period)	0 0	5050 (3730)	5090 (3760)	7180 (5300)	8250 (6092)	2.7
	1740 (1280) Total orbit	0 0	5050 (3730)	5090 (3760)	7180 (5300)	8920 (6580)	2.9
(Y-POP, X-IOP) $\lambda = 0$	0 0	0 0	7340 (5420)	0 0	7340 (5420)	7340 (5420)	2.4

A momentum absorption capability described as $H_{CMG}^{(transition)}$ is also required. This is because of the fact that when the CMG system takes over control from the orbiter's ACPS, the residual momentum left by the baseline system must be absorbed. The magnitude of this transition momentum is

$$H_{CMG}^{(trans)} = 3320 \text{ N-m-sec (2450 ft-lb-sec)}.$$

This event, however, occurs only once per mission and is a negligible factor in sizing the CMG system.

Aerodynamics torques also act on the orbiter and induce an angular momentum that must be stored by the CMG system. It is assumed that the aerodynamic induced momentum is

$$H_{CMG}^{(aero)} = 130 \text{ N-m-sec (95 ft-lb-sec)}.$$

Table IV-14 is a summary of the CMG momentum requirements.

Table IV-14 CMG Momentum Requirements, X-IOP

$\left\|\vec{H}_a\right\| = 1740$ N-m-sec (1280 ft-lb-sec)
$\left\|\vec{H}_c\right\|_p = 7180$ N-m-sec (5300 ft-lb-sec)
$H^{(aero)} = 130$ N-m-sec (95 ft-lb-sec)
$H_{CMG}^{(STAB+aero)} = 9050$ N-m-sec (6675 ft-lb-sec)
$H_{CMG}^{(man)} = 5820$ N-m-sec (4300 ft-lb-sec)
$H_{CMG}^{(trans)} = 3320$ N-m-sec (2450 ft-lb-sec)

The momentum capacity calculated for stabilization alone is 8920 N-m-sec (6580 ft-lb-sec) and includes the maximum expected accumulated momentum per orbit and the peak cyclic gravity gradient component. Adding the aerodynamics-induced requirement to this yields a subtotal of 9050 N-m-sec (6675 ft-lb-sec).

The momentum capacity calculated for maneuvering at 2 degrees/minute is 5820 N-m-sec (4300 ft-lb-sec).

The momentum capacity calculated for the transition from ACPS to CMG control is 3320 N-m-sec (2450 ft-lb-sec).

In sizing a CMG system, it is only necessary to size to the largest of the above momentum requirements, since the three momentums will not occur simultaneously. For the X-IOP inertial attitude the largest momentum requirement is caused by the stabilization and aerodynamic momentum of 9050 N-m-sec (6675 ft-lb-sec).

The angular momentum that accumulates on the CMGs during each orbital period causes a bias to build up. This bias, if not dumped, will eventually cause the CMGs to become saturated and ineffective. The amount of angular momentum required to be dumped per orbit, while maintaining the X-IOP configuration, is

$\left|\vec{H}_a\right|$ = 1740 N-m-sec/orbit (1280 ft-lb-sec/orbit).

2) <u>RCS Momentum Requirements</u> - The low-thrust RCS must be capable of delivering sufficient momentum to the orbiter to provide:

1) Stability to the vehicle, i.e., reaction against gravity gradient torques $\left[\text{this term is designated } H_{RCS}^{(STAB)}\right]$;
2) Reaction to aerodynamic torques $\left[\text{designated by } H_{RCS}^{(aero)}\right]$;
3) Attitude maneuvering of the vehicle $\left[\text{designated by } H_{RCS}^{(man)}\right]$;
4) Residual momentum absorption left by the baseline ACPS when the low-thrust RCS takes over control $\left[\text{designated by } H_{RCS}^{(trans)}\right]$.

The rectified gravity-gradient momentums H_{gr}, accumulated during one orbit are calculated on a per axis basis to be:

H_{grx} = 1745 N-m-sec/orbit (1285 ft-lb-sec/orbit);

H_{gry} = 40,600 N-m-sec/orbit (30,000 ft-lb-sec/orbit);

H_{grz} = 40,600 N-m-sec/orbit (30,000 ft-lb-sec/orbit).

The total rectified gravity-gradient momentum that the X-IOP Shuttle orbiter stabilization RCS must absorb is

H_{gr} = 83,000 N-m-sec/orbit (61,285 ft-lb-sec/orbit).

Aerodynamic momentum compensation requirements are assumed to be 5% of H_{gr}, as calculated for the X-POP attitude

$$H_{RCS}^{(aero)} \Big|_{\substack{\text{Total}\\\text{Mission}}} = 30{,}600 \text{ N-m-sec/mission (22,600 ft-lb-sec/mission)}$$

The RCS momentum requirements for attitude maneuvers are calculated on a per axis basis. The maneuver rate was taken as 2 degrees/minute about each axis. To maintain the X-IOP attitude constraint, the momentum H_y must remain zero. Thus

$$H_{RCS}^{(m)} = 2\left(H_x + H_z\right)$$

$$H_{RCS}^{(m)} = 12{,}950 \text{ N-m-sec/maneuver (9554 ft-lb-sec/maneuver).}$$

Half of $H_{RCS}^{(m)}$ is used to put the orbiter in motion; the other half is required to stop it after it has passed through the desired rotation angle.

In addition to the above momentum, it will also be necessary to provide limit cycle momentum, $H_{RCS}^{(LC)}$, for those periods of the orbit where the gravity gradient and aerodynamic torques are not large enough to prevent the RCS from operating in its deadband limits. The limit cycle momentum was estimated to be 32,200 N-m-sec (23,800 ft-lb-sec) for the 7-day mission.

A summary of RCS angular momentum requirements is presented in Table IV-15. These values are then used in determining the RCS impulse requirements. The total RCS impulse required for the 7-day mission is summarized in Table IV-16. This impulse is based on an average moment arm of 35 feet for each axis and assumes a total of 106 orbits and 28 maneuvers during the 7-day mission.

Table IV-15 RCS Momentum Requirements, X-IOP

	$H_{RCS}^{(m)}$	=	362,000 N-m-sec	(267,512 ft-lb-sec)
	$H_{RCS}^{(STAB)}$	=	8,800,000 N-m-sec	(6,496,210 ft-lb-sec)
	$H_{RCS}^{(aero)}$	=	30,600 N-m-sec	(22,600 ft-lb-sec)
	$H_{RCS}^{(trans)}$	=	5,780 N-m-sec	(4,275 ft-lb-sec)
	$H_{RCS}^{(LC)}$	=	32,200 N-m-sec	(23,800 ft-lb-sec)
$H_{RCS}^{(Total)}$	Total Mission	=	9,230,580 N-m-sec	(6,814,397 ft-lb-sec)

Note: Total mission requirements are based on 106 orbits and 28 maneuvers per 7-day mission.

Table IV-16 RCS Impulse Requirements, X-IOP

$\Sigma F\Delta t\|_{gg}$	=	822,000 N-sec	(185,000 lb-sec)
$\Sigma F\Delta t\|_{aero}$	=	2,900 N-sec	(650 lb-sec)
$\Sigma F\Delta t\|_{LC}$	=	3,030 N-sec	(680 lb-sec)
$\Sigma F\Delta t\|_{man}$	=	102,500 N-sec	(23,000 lb-sec)
$\Sigma F\Delta t\|_{tran}$	=	542 N-sec	(122 lb-sec)
$\Sigma F\Delta t\|_{loss}$	=	0	(0)
Total RCS I_{sp}	=	930,972 N-sec/mission	(209,452 lb-sec/mission)

Note: Considers 106 orbits/mission and 28 maneuvers/mission.

c. Control Requirements for Z-POP Inertial Attitude - This section discusses the momentum requirements for the Shuttle orbiter in a Z-POP attitude. The analysis assumes a misalignment, from a true Z-POP attitude, of 1 degree about the X and Y axes.

1) CMG Momentum Requirements - The stabilization momentum for the Z-POP inertial attitude will consist of the accumulated momentum and the peak cyclic momentum on a per-axis basis.

The accumulated momentum magnitudes are:

X-Axis--H_{ax} = 60.3 N-m-sec/orbit (44.5 ft-lb-sec);

Y-Axis--H_{ay} = 1600 N-m-sec/orbit (1180 ft-lb-sec);

Z-Axis--H_{az} = 0.

The total accumulated momentum magnitude is given by

$$\left|\vec{H}_a\right| = \left(H_{ax}^2 + H_{ay}^2 + H_{az}^2\right)^{1/2}$$

$$= 1600 \text{ N-m-sec/orbit (1180 ft-lb-sec/orbit)}$$

The cyclic momentum magnitudes are:

X-Axis--$H_{cx} = 3.55 \left(\cos 2\omega_o t - \sin 2\omega_o t\right)$;

Y-Axis--$H_{cy} = 94 \left(\cos 2\omega_o t + \sin 2\omega_o t\right)$;

Z-Axis--$H_{cz} = 5200 \left(\cos 2\omega_o t\right)$.

The peak cyclic momentum magnitude occurs at $\omega_o t = 2\pi$--

$\left|H_{cx}\right|_p$ = 4.82 N-m-sec (3.55 ft-lb-sec)

$\left|H_{cy}\right|_p$ = 127.0 N-m-sec (94.0 ft-lb-sec)

$\left|H_{cz}\right|_p$ = 7050 N-m-sec (5200 ft-lb-sec).

The total peak cyclic momentum magnitude is given by

$$\left|H_c\right|_{peak} = \left(H_{cx}^2 + H_{cy}^2 + H_{cz}^2\right)_p^{\frac{1}{2}}$$

$$= 7050 \text{ N-m-sec } (5200 \text{ ft-lb-sec}).$$

The CMG momentum storage requirement for stabilization in the Z-POP attitude, allowing 1 degree errors in rotation about the X and Y axes, becomes

$$H_{CMG}^{(STAB)} = \left|\vec{H}_a\right| + \left|\vec{H}_c\right|_p$$

$$= 8650 \text{ N-m-sec/orbit } (6380 \text{ ft-lb-sec}).$$

Add 5% to this value for aerodynamic torque compensation, so that

$$H_{CMG}^{(aero)} = 130 \text{ N-m-sec/orbit } (95 \text{ ft-lb-sec/orbit}),$$

and obtain

$$H_{CMG}^{(STAB+aero)}\Bigg|_{Total} = 8780 \text{ N-m-sec/orbit } (6475 \text{ ft-lb-sec/orbit}).$$

This value can be satisfied with three ATM-type CMGs that would provide 6900 ft-lb-sec; therefore, stabilization in the Z-POP attitude for a complete orbit without desaturation can be obtained.

2) RCS Momentum Requirements - The accumulated rectified angular momentums acting on the three vehicle axes are

X-Axis--H_{grx} = 68.5 N-m-sec/orbit (50.5 ft-lb-sec);

Y-Axis--H_{gry} = 1830 N-m-sec/orbit (1350 ft-lb-sec);

Z-Axis--H_{grz} = 56,500 N-m-sec/orbit (41,600 ft-lb-sec).

The total rectified gravity-gradient momentum that the Z-POP Shuttle orbiter RCS must absorb during each orbit equals

$$H_{gr} = H_{grx} + H_{gry} + H_{grz}$$

$$= 58{,}400 \text{ N-m-sec/orbit } (43{,}000 \text{ ft-lb-sec/orbit}).$$

For a 7-day mission containing 106 orbits

$$H_{gr}^{(STAB)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 6{,}200{,}000 \text{ N-m-sec } (4{,}558{,}000 \text{ ft-lb-sec}).$$

The additional Z-POP momentum requirements for maneuvering, limit cycle, aerodynamic drag compensation, and transition from Shuttle baseline to RCS are similar to those calculated for the X-IOP attitude.

The angular momentum requirements for maneuvering depend on the moment of inertia about the Z-axis, I_z, and the maneuver rate, ω_m. If the Z-POP attitude is to be maintained during a maneuver, then H_x and $H_y = 0$. The values calculated for X-IOP, however, include an H_x component. Since the magnitude of H_x is only 10% of H_z, no appreciable error is included by using $H_{RCS}^{(m)} = 9554$ ft-lb-sec $\left(\text{the X-IOP value of } H_{RCS}^{(m)}\right)$.

The total Z-POP RCS momentum may then be obtained as follows:

$$H_{RCS}^{(m)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 362{,}000 \text{ N-m-sec } (267{,}512 \text{ ft-lb-sec});$$

$$H_{RCS}^{(LC)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 32{,}200 \text{ N-m-sec } (23{,}800 \text{ ft-lb-sec});$$

$$H_{RCS}^{(aero)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 30{,}600 \text{ N-m-sec } (22{,}600 \text{ ft-lb-sec});$$

$$H_{RCS}^{(STAB)}\Big|_{\substack{\text{Total}\\ \text{Mission}}} = 6{,}200{,}000 \text{ N-m-sec } (4{,}558{,}000 \text{ ft-lb-sec});$$

$$H_{RCS}^{(trans)}\Big|_{\substack{\text{Total}\\ \text{Mission}}} = 5800 \text{ N-m-sec } (4275 \text{ ft-lb-sec}).$$

Therefore,

$$H_{RCS\,(Z\text{-}POP)}^{(total)}\Big|_{\substack{\text{Total}\\ \text{Mission}}} = 6{,}600{,}000 \text{ N-m-sec } (4{,}876{,}400 \text{ ft-lb-sec})$$
(for a maneuvering rate of 2 deg/min).

d. Control Requirements for X-POP Inertial Attitude - This section discusses the momentum requirements for the Shuttle orbiter in the X-POP attitude. The analysis assumes a misalignment from the true X-POP attitude by two small Y and Z axis rotational errors of 1 degree.

1) CMG Momentum Requirements - The analysis for this section determines the magnitudes of the accumulated momentum and the peak cyclic momentum on a per axis basis.

The Shuttle orbiter external torque environment for this attitude and an altitude of 270 nautical miles is again assumed to be primarily gravity-gradient induced torques with aerodynamic-induced torques contributing only slightly, and being of the same magnitude as those calculated for the X-IOP attitude.

The values computed are based on the following assumptions:

1) The desired Shuttle orbiter attitude is the X-POP;

2) The actual attitude is misaligned from true X-POP by a 1 degree rotation about both the Y and Z axes;

3) Noncyclic momentum is accumulated for one complete orbit, while the vehicle is inertially held in its desired orientation.

The magnitude of the accumulated momentum $\left|\vec{H}_a\right|$, for a complete orbit, and the magnitude of the peak cyclic momentum components are:

$$\left|\vec{H}_a\right| = \left(H^2_{ax} + H^2_{ay} + H^2_{az}\right)^{\frac{1}{2}}$$

$$= 3\pi\omega_o\varepsilon\left[\left(I_z - I_x\right)^2 + \left(I_y - I_x\right)^2\right]^{\frac{1}{2}}$$

$$= 2240 \text{ N-m-sec/orbit (1655 ft-lb-sec/orbit);}$$

$$\left|H_{cx}\right|_p = 282 \text{ N-m-sec (208 ft-lb-sec);}$$

$$\left|H_{cy}\right|_p = 127 \text{ N-m-sec (94 ft-lb-sec);}$$

$$\left|H_{cz}\right|_p = 171 \text{ N-m-sec (126 ft-lb-sec).}$$

On a conservative basis, the total peak cyclic momentum can be computed as

$$\left|\vec{H}_c\right|_p = \left(\left|H_{cx}\right|^2_p + \left|H_{cy}\right|^2_p + \left|H_{cz}\right|^2_p\right)^{\frac{1}{2}}$$

$$= 352 \text{ N-m-sec (260 ft-lb-sec).}$$

The CMG gravity-gradient momentum storage requirement, $H^{(STAB)}_{CMG}$, for the X-POP attitude with 1-degree errors about the Y and Z axes is

$$H^{(STAB)}_{CMG} = \left|\vec{H}_a\right| + \left|\vec{H}_c\right|_p$$

$$= 2600 \text{ N-m-sec (1915 ft-lb-sec).}$$

Aerodynamic torques also act on the orbiter and induce an angular momentum that must be stored by the CMG system. It is assumed that the aerodynamic momentum storage requirement is the same as that calculated for the X-IOP attitude. This value is

$$H^{(aero)}_{CMG} = 130 \text{ N-m-sec (95 ft-lb-sec).}$$

Therefore,

$$H_{CMG}^{(STAB)} + H_{CMG}^{(aero)} = 2720 \text{ N-m-sec (2010 ft-lb-sec)}$$

2) RCS Momentum Requirements - The Shuttle orbiter is assumed to be stabilized in the X-POP attitude. The orbiter is also assumed to be misaligned from its true X-POP attitude by two small Y and Z axis rotational errors, ε_y and ε_z, each of which was set equal to 1 degree.

The analysis for this section determines the magnitudes of the rectified angular momentum axial components. Results indicate:

H_{grx} = 2200 N-m-sec/orbit (1620 ft-lb-sec/orbit);

H_{gry} = 1830 N-m-sec/orbit (1350 ft-lb-sec/orbit);

H_{grz} = 1760 N-m-sec/orbit (1295 ft-lb-sec/orbit).

The total required RCS momentum per orbit for stabilization to counteract the gravity-gradient torques is

$$H_{RCS}^{(STAB)_{gg}} = 5800 \text{ N-m-sec/orbit (4265 ft-lb-sec/orbit)}.$$

For a complete 7-day mission consisting of 106 orbits, the total RCS momentum requirement to counteract the gravity gradient torques is

$$\left. H_{RCS}^{(STAB)_{gg}} \right|_{\substack{\text{Total} \\ \text{Mission}}} = 611{,}000 \text{ N-m-sec (452,090 ft-lb-sec)}.$$

To determine the maneuvering momentum requirements the maneuver rate was taken as 2 degrees/minute as a maximum. Furthermore, the X-POP attitude was assumed to be maintained. Thus, only H_x will be allowed to be nonzero. Therefore,

$$H_{RCS}^{(m)} = \frac{1290 \text{ N-m-sec}}{\text{Maneuver}} \text{ (954 ft-lb-sec/maneuver)}.$$

Considering there are to be 28 maneuvers per 7-day mission yields

$$H_{RCS}^{(m)gg}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 36{,}200\ \frac{\text{N-m-sec}}{\text{mission}}\ (26{,}712\ \text{ft-lb-sec/mission}).$$

The additional X-POP momentum requirements for aerodynamic drag, limit cycle, and transition are as follows: $H^{(aero)}$ is 5% of $H^{(STAB)}$, and $H^{(LC)}$ is 5% of $\left[H^{(STAB)} + H^{(aero)}\right]$. Therefore, in summary:

$$H_{RCS}^{(aero)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 30{,}600\ \text{N-m-sec}\ (22{,}600\ \text{ft-lb-sec});$$

$$H_{RCS}^{(trans)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 5780\ \text{N-m-sec}\ (4275\ \text{ft-lb-sec});$$

$$H_{RCS}^{(STAB)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 612{,}000\ \text{N-m-sec}\ (452{,}090\ \text{ft-lb-sec});$$

$$H_{RCS}^{(LC)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 32{,}200\ \text{N-m-sec}\ (23{,}800\ \text{ft-lb-sec});$$

$$H_{RCS}^{(m)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 362{,}000\ \text{N-m-sec}\ (267{,}512\ \text{ft-lb-sec});$$

$$H_{RCS}^{(total)}\Big|_{\substack{\text{Total}\\\text{Mission}}} = 1{,}042{,}580\ \text{N-m-sec}\ (770{,}400\ \text{ft-lb-sec}).$$

e. Summary of Angular Momentum Requirements for CMG and RCS Control - The summary of angular momentum requirements discussed in the previous sections is presented for CMG data in Table IV-17; for RCS data in Table IV-18.

The results are tabulated for three major vehicle attitudes: the X-POP attitude with a 1 degree angular misalignment about the Y and Z axis; the Z-POP attitude with a 1 degree angular misalignment about the X and Y axis; and the X-IOP attitude calculated for maximum angular momentum requirements. For the X-POP and Z-POP cases, the 1-degree misalignment is considered conservative since in reality the control system should be capable of holding the desired attitude to within 0.5 degree.

The X-IOP attitude allows the largest freedom for maneuver, since rotation can take place about the X axis and about the axis perpendicular to the orbital plane. The angular momentum requirements for maneuver are calculated on the basis of a 2 degree/minute maneuver rate about the Z axis (the axis having the largest moment of inertia). This same value of $H^{(man)}$ is then considered as the $H^{(man)}$ requirement for both the Z-POP and the X-POP attitudes. This is definately proper for the Z-POP attitude consideration since any maneuver must be only about the Z axis. Given the X-IOP maneuver capacity, the X-POP attitude maneuver rate will be much larger since the moment of inertia about the X axis is 10 times smaller than about the Z axis.

The angular momentum requirement, $H^{(trans)}$, for absorbing the residual momentum left by the baseline system when the CMG or RCS takes over control is independent of the final attitude assumed. Therefore, $H^{(trans)}$ has the same value for X-POP, Z-POP, and X-IOP for the given control system (i.e., CMG or RCS).

The magnitude of the peak cyclic momentum vector (Table IV-17) is the largest for the X-IOP attitude and the Z-POP attitude with values of 5300 ft-lb-sec and 5200 ft-lb-sec, respectively. The X-POP attitude has comparatively small peak cyclic momentum components. $H^{(aero)}$ is also comparatively smaller taken as 5% of

$$\left|H_a\right| + \left|\vec{H}_c\right|_p .$$

Table IV-17 Summary of Angular Momentum Requirements for CMG Control

Momentum Source	X-POP 1-deg Misalignment about Y & Z N-m-sec	ft-lb-sec	Z-POP 1-deg Misalignment about X & Y N-m-sec	ft-lb-sec	X-IOP Maximum at λ = 44.8 deg N-m-sec	ft-lb-sec
H_{ax}	0	0	60.3	44.5	1740	1280
H_{ay}	1580	1170	1600.0	1180.0	0	0
H_{az}	1540	1140	0.0	0.0	0	0
$\lvert\vec{H}_a\rvert = \left(H_{ax}^2 + H_{ay}^2 + H_{az}^2\right)^{1/2}$	2240	1655	1600.0	1180.0	1740	1280
H_{cxp}	282	208	4.82	3.55	0	0
H_{cyp}	127	94	127.0	94.00	5050	3730
H_{czp}	171	126	7050.0	5200	5100	3760
$\lvert\vec{H}_c\rvert_p = \left(H_{cxp}^2 + H_{cyp}^2 + H_{czp}^2\right)^{1/2}$	352	260	7050.0	5200	7180	5300
$H_{X\text{-}IOP}^{(aero)} = .05\left[\lvert\vec{H}_a\rvert + \lvert\vec{H}_c\rvert_p\right]$	130	95	130	95	130	95
$H_{CMG}^{(STAB + aero)} = \lvert\vec{H}_a\rvert + \lvert\vec{H}_c\rvert_p + H^{(aero)}$	2720	2010	8770	6475	9040	6675
$H_{Z\text{-}Axis}^{(maneuver)}$ 2 deg/min	5820	4300	5820	4300	5820	4300
$H^{(transition)}$	3320	2450	3320	2450	3320	2450

Table IV-18 Summary of Angular Momentum Requirements for RCS Control

Momentum Source	X-POP 1-deg Misalignment about Y & Z N-m-sec	ft-lb-sec	Z-POP 1-deg Misalignment about X & Y N-m-sec	ft-lb-sec	X-IOP Maximum at λ = 44.8 deg N-m-sec	ft-lb-sec
$H^{(gg)}$	612,000	452,090	6,200,000	4,558,000	8,800,000	6,496,210
$H^{(aero)}$	30,600	22,600	30,600	22,600	30,600	22,600
$H^{(Lc)}$	32,200	23,800	32,200	23,800	32,200	23,800
$H^{(m)}$	362,000	267,512	362,000	267,512	362,000	267,512
$H^{(trans)}$	5,780	4,275	5,780	4,275	5,780	4,275
$H^{(Total)}$	1,042,580	770,400	6,630,580	4,876,400	9,230,580	6,814,400

The magnitude of the accumulated momentum per orbit (Table IV-17) for CMG control is largest for the X-POP attitude but is only approximately 20% smaller for the Z-POP and X-IOP attitudes.

Assuming a single Skylab ATM-type CMG having an angular momentum capacity of 2300 ft-lb-sec, the X-POP attitude requires two CMGs, the Z-POP attitude requires three CMGs, and the X-IOP attitude requires three CMGs. This is arrived at by assuming the required angular momentum capacity to be the larger of the stabilization requirements, $H^{(STAB)}$, or the maneuver requirement, $H^{(man)}$. In the X-IOP attitude, the calculated value is actually just slightly above that which could be handled by three CMGs. If one extra CMG is added to each described attitude case for contingency purposes, the totals are:

For X-POP--three CMGs;

For Z-POP--four CMGs;

For X-IOP--four CMGs.

The RCS angular momentum requirements are summarized in Table IV-18 for each attitude, and are largest for X-IOP and smallest for X-POP.

The requirements for compensating aerodynamic drag, transition, maneuvering, and limit cycle allowance are assumed identical for all attitudes since in all cases they are smaller than the gravity-gradient compensation requirements.

f. Sizing CMG and a Low-Thrust RCS to Control the Orbiter - As mentioned previously, CMGs were recommended as the preferred system for controlling the attitude of the Shuttle orbiter. This recommendation was based primarily on the probable contamination of astronomy instruments, should RCS firings be used for Shuttle control. However, there is still enough resistance to the CMG system to justify sizing CMGs and a low-thrust RCS. Consequently, this section of the report will identify the weight and power for both types of systems. For each of the systems, sufficient redundancy was included to obtain a high reliability (about 0.999) for a 7-day mission.

1) <u>Weight Comparison</u> - The angular momentum requirements for CMG and RCS control are summarized in Tables IV-17 and IV-18. In Figure IV-16, plots are shown of total RCS weight as a function of total impulse for cold gas, hydrazine monopropellant, and hydrazine bipropellant using the specific impulse values noted.

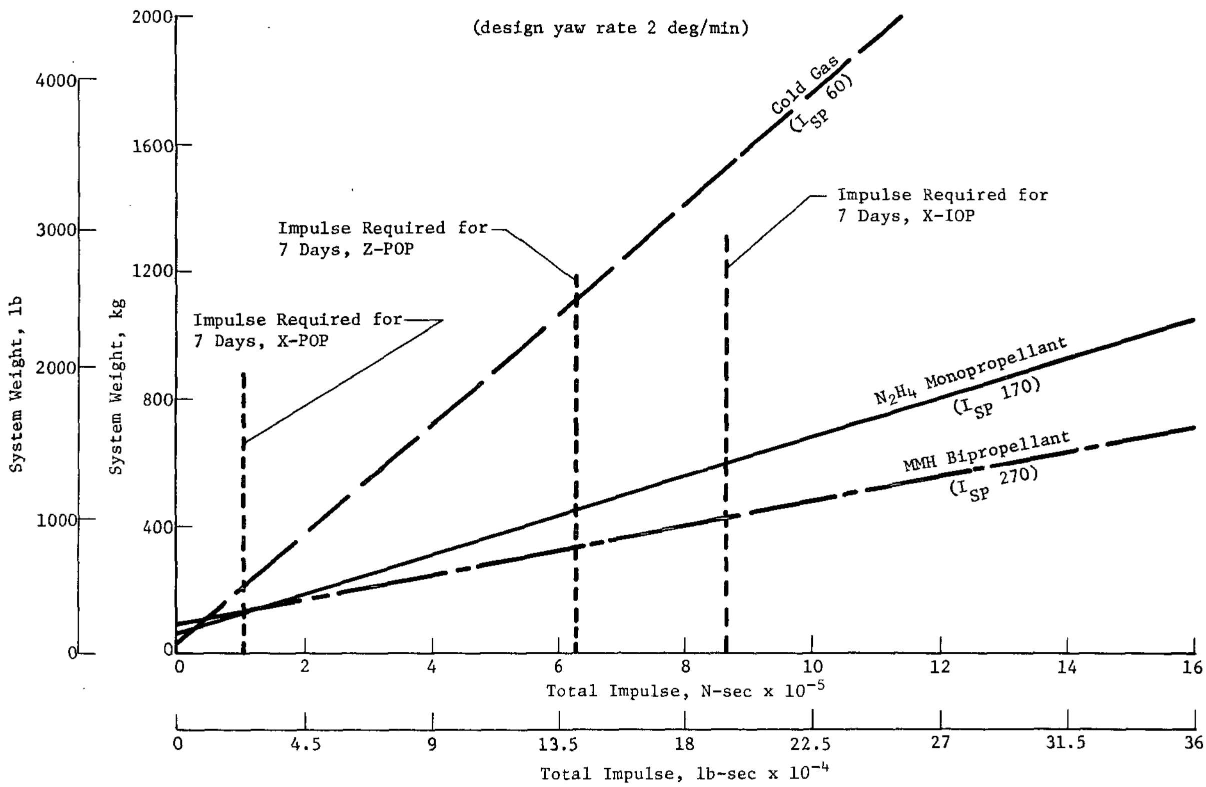

Figure IV-16 RCS Weight

In estimating the RCS weight it was assumed that thrusters, control valves, and other critical components were designed in redundant pairs. The vertical lines on the figure indicate the impulse required for RCS control of the Shuttle orbiter for 106 orbits and 28 maneuvers during a 7-day mission. For missions longer than 7 days, the impulse and weights can be estimated by a direct ratio of the orbits.

In sizing the CMG systems it was assumed that ATM-type CMGs would be used to satisfy the momentum requirements. Each ATM CMG has a momentum capacity of 3120 N-m-sec (2300 ft-lb-sec). Sufficient CMGs were provided to satisfy the maximum momentum requirement in terms of stabilization and aerodynamics, maneuvering, or transition. In addition, an extra CMG was added for contingency purposes. The total ATM CMGs for each inertial attitude were:

X-POP--three CMGs;

Z-POP--four CMGs;

X-IOP--four CMGs.

Table IV-19 is a summary of the weight requirements for a hydrazine monopropellant RCS and a CMG system for each of the inertial attitudes considered. The CMG weight includes the cabling and mounting hardware plus all necessary electronic hardware. The RCS shown is a hydrazine monpropellant system with a specific impulse of 170 seconds. The weight difference between the RCS and CMG systems varies between 500 and 570 kilograms (1100 to 1250 lb) with the CMG system weighing anywhere from 1.6 to 5 times the RCS.

Table IV-19 Weight Summaries for CMG and RCS Monopropellant Systems

		X-POP-I*	Z-POP-I†	X-IOP-I§
Weight Requirements, kg (lb)	CMG System	705 (1555)	938 (2068)	938 (2068)
	RCS 7 days I_{sp} = 170 sec	135 (298)	440 (972)	600 (1324)

*Requires viewing with both telescopes parallel to the X-axis with possible reflection interference from Shuttle surfaces. Requires deployment of telescope gimbals out of the payload bay. Requires coarse gimbal pointing variations (28 or 14 deg) in one plane during a 7-day mission.

†Requires coarse gimbal pointing variations (28 or 14 deg) in one plane during 7-day mission.

§No constraints on Y and Z axis. Does not require coarse gimbal freedom for pointing. Requires complex maneuvers to desaturate CMGs.

2) <u>Electrical Power Comparison</u> - In Table IV-20, the electrical power requirements for both CMG control and low-thrust RCS control are presented for the attitudes of X-POP, Z-POP, and a worst-case X-IOP. The values are conservative in the case of peak CMG power, as an extra CMG is carried to provide the required capability with one CMG inoperative. The estimates apply to the case of design maneuver rates of 2 degrees/minute about the axis of greatest inertia.

Table IV-20 Power Summaries for CMG Systems and RCS

		X-POP-I	Z-POP-I	X-IOP-I
Power, watts	CMG System	144 Average 576 Peak	192 Average 768 Peak	192 Average 768 Peak
	RCS System	15 Average 135 Peak	36 Average 135 Peak	45 Average 135 Peak

The power requirements for the RCS system will not vary appreciably whether the RCS uses cold gas, N_2H_4 monopropellant, or a bipropellant.

The power requirements for the CMG system include the power for the CMGs and the CMG inverter assemblies. The RCS power is for the operation of the RCS thruster control circuitry.

4. <u>Recommended Solar Payload Configuration</u>

The recommended configuration for the ASM solar payload is the nondeployed concept presented in Figure IV-15. The recommended inertial attitude for the Shuttle orbiter during solar observations is the Z-POP.

Table IV-21 is a summary of the pertinent characteristics for each of the configurations and inertial attitudes considered in this analysis. As can be seen from the table, the baseline deployed X-POP and the modified deployed X-POP concepts of Figures IV-12 and IV-13 are not compatible with the new ground rule that states "deployed payloads cannot exceed 13.72 meters (45 ft) in length." Therefore, these concepts are not acceptable. The nondeployed X-POP concept of Figure IV-4 satisfies the new ground rules, but does have the undesirable characteristic of receiving reflections from the Shuttle structure that could degrade the performance of the Coronagraphs. The final two concepts, nondeployed Z-POP and nondeployed X-IOP, both satisfy the revised ground rules and provide excellent viewing potential for the instruments. There is a total weight penalty of approximately 187 kilograms (413 lb) but the viewing advantages are significant enough to recommend the nondeployed concept shown in Figure IV-15.

Table IV-21 Comparison of Solar Payload Concepts

CONCEPT	CHARACTERISTICS				
	Compatible with Stellar	Weight, kg (lb)	Viewing	Compatible with New Ground Rules	Comment
Deployed X-POP (baseline)	Yes	13,068 (28,809)	Excellent	No	Unacceptable
Modified Deployed X-POP (modified baseline)	No	13,703 (30,209)	Excellent	No	Unacceptable
Nondeployed X-POP	Yes	12,227 (26,956)	Shuttle Reflec- tions	Yes	Undesirable
Nondeployed Z-POP	Yes	12,414 (27,369)	Excellent	Yes	Acceptable
Nondeployed X-IOP	Yes	12,414 (27,369)	Excellent	Yes	Acceptable

It should be noted that although the Z-POP inertial attitude is recommended for the solar payload, the CMG stabilization system for the Z-POP will also provide the capability for the X-IOP. The primary reason for selecting the Z-POP for the solar payload was to minimize the maneuvering that would be required to desaturate the CMGs each orbit. With a Z-POP inertial attitude, the maneuvers would be very small angles each orbit that would result in little, if any, loss in observation time.

C. ON-ORBIT ACCESS

At the final review of the 9-month Astronomy Sortie Missions study, conducted at MSFC in September 1972, the Sortie Optical Astronomy Group requested that the follow-on study include investigation of several alternative concepts to provide on-orbit shirtsleeve access to the focal planes of the stratoscope III, infrared, and photoheliograph telescopes. These alternative concepts were defined by Martin Marietta and discussed at a coordination meeting held at MSFC in February, 1973. At this meeting, one of the alternatives was selected as the concept to be recommended for Astronomy Sortie missions. At the same meeting, the COR NASA/MSFC deleted the requirement for on-orbit access to the infrared telescope. However, all data resulting from the investigation are included in this report.

1. Ground Rules and Assumptions

The following ground rules and assumptions were adopted for the on-orbit access studies:

1) The telescopes to be studied include--
   - The 100-centimeter photoheliograph being defined in the Large Solar Observatory (LSO) study under contract to NASA/MSFC,
   - The stratoscope III will be adopted from the 120-centimeter design being done by Itek,
   - The 100-centimeter IR telescope, based on the work performed by Martin Marietta and Itek earlier in this study;
2) The gas bearing concept defined for the AMES C141 IR telescope will be analyzed to determine applicability to Astronomy Sortie missions;
3) Sortie Lab data were extracted from Reference 2 and updated by Reference 7.

2. Selection of Alternatives

The advantages of providing shirtsleeve on-orbit access can be grouped into scientific and engineering categories.

Scientifically, it is advantageous to be able to make adjustments to the telescope and instruments (to ensure optimum performance of the equipment) before starting an observation. The adjustments can be done remotely, from the Sortie Lab. However, this requires additional hardware and adds to complexity of operation. Astronomers are also used to monitor image quality during an observation, in order to judge such factors as "seeing" and atmospheric extinction. These factors, of course, do not apply in space, but others, such as telescope performance or guide errors, could still be monitored. Again, remote observation is possible but more complex.

Engineering advantages for providing manned access to the equipment include the capability for inflight repairs, and avoiding some automation, such as remote filter selection or moving a new instrument into the telescope optical axis by remote control.

When these scientific and engineering motivations for manned access are analyzed, it is apparent that only one calls for access during an observation. All except the monitoring of image quality take place between observations; thus, if remote monitoring and some corrective functions such as focus adjust are provided, schemes may be considered that provide access only between observations.

The baseline accommodation mode (Ref 1) does not incorporate provisions for on-orbit access. Telescopes are located on hemispherical viewing mounts, attached to the pallet. Figure IV-17 shows the baseline concept and the on-orbit access concepts discussed below.

Two concepts for providing manned access to the telescope focal plane were studied: the airlock/hangar concept, and the folded optics concept.

The airlock/hangar concept allows the telescope to operate on its hemispherical viewing mount (located on the pallet) during observations. It is brought back to the launch position for access from the Sortie Lab. This scheme does not allow access during observations; therefore, monitoring and some adjustments must be done remotely. Also, the Sortie Lab airlock must be operated each time access is required. The advantages of this scheme are that it minimizes the impact on the telescope design and allows the telescope to be pointed over a large part of the sky without reorienting the Shuttle orbiter.

The second concept for providing shirtsleeve access brings the telescope image into the Sortie Lab. Two variations of the folded optics concept were developed: one uses a gas bearing; the other incorporates a mechanical gimbal for supporting the telescope (this scheme allows continuous access to the instruments, even during observations). Bringing the focal surface into the Sortie Lab involves impacts on the telescope optics, as discussed in the following paragraphs.

3. Telescope Definitions

The three intermediate class telescopes selected for the on-orbit access study are defined in Reference 1. These baseline designs do not include provisions for on-orbit shirtsleeve access. Brief descriptions of the baseline telescopes are included below, along with descriptions of the modified telescopes, to illustrate the modifications required to achieve compatibility with shirtsleeve on-orbit access concepts.

a. Baseline

1) Photoheliograph - The baseline 100-centimeter, f/3.8-f/50 photoheliograph is a scaled-up version of the 65-centimeter instrument defined by BBRC under NASA contract NAS8-30190. The baseline design (Fig. IV-18) has an overall length of 4.58 meters (180 in), which represents the maximum allowable length of the telescope when integrated into the baseline solar payload (which includes two telescope groups). The instruments are located in a housing lying along the side of the telescope tube.

2) Stratoscope III - Figure IV-19 shows the baseline 120-centimeter, f/2.2-f/12 stratoscope as defined by Itek. The optical system was modeled after the Itek LST, and the telescope is intended to serve as an engineering model of the LST. Overall length of the telescope is 4.22 meters (166 in).

3) Infrared Telescope - The baseline 100-centimeter, f/1.5-f/10 IR telescope was defined by Martin Marietta and Itek (Fig. IV-20). The design is based on an integral tank approach, using liquid neon as the coolant. Coolant is circulated by capillary forces, rather than a pump system. This method avoids the disturbances caused by mounting rotating machinery and fluid flow control components on the telescope. The design shown allows either of two instruments to be remotely positioned at the telescope focal plane.

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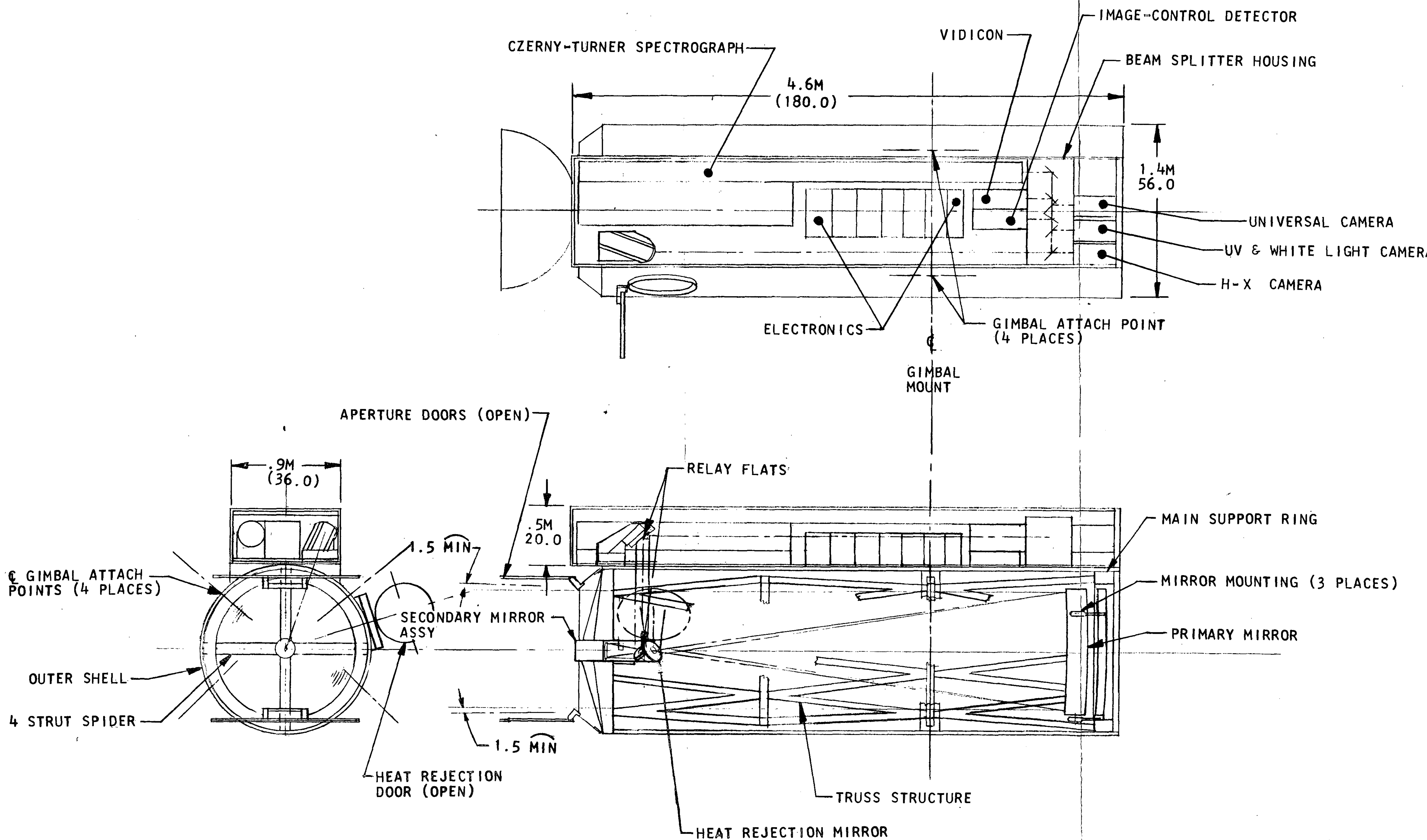

Figure IV-18 Photoheliograph (100 cm)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

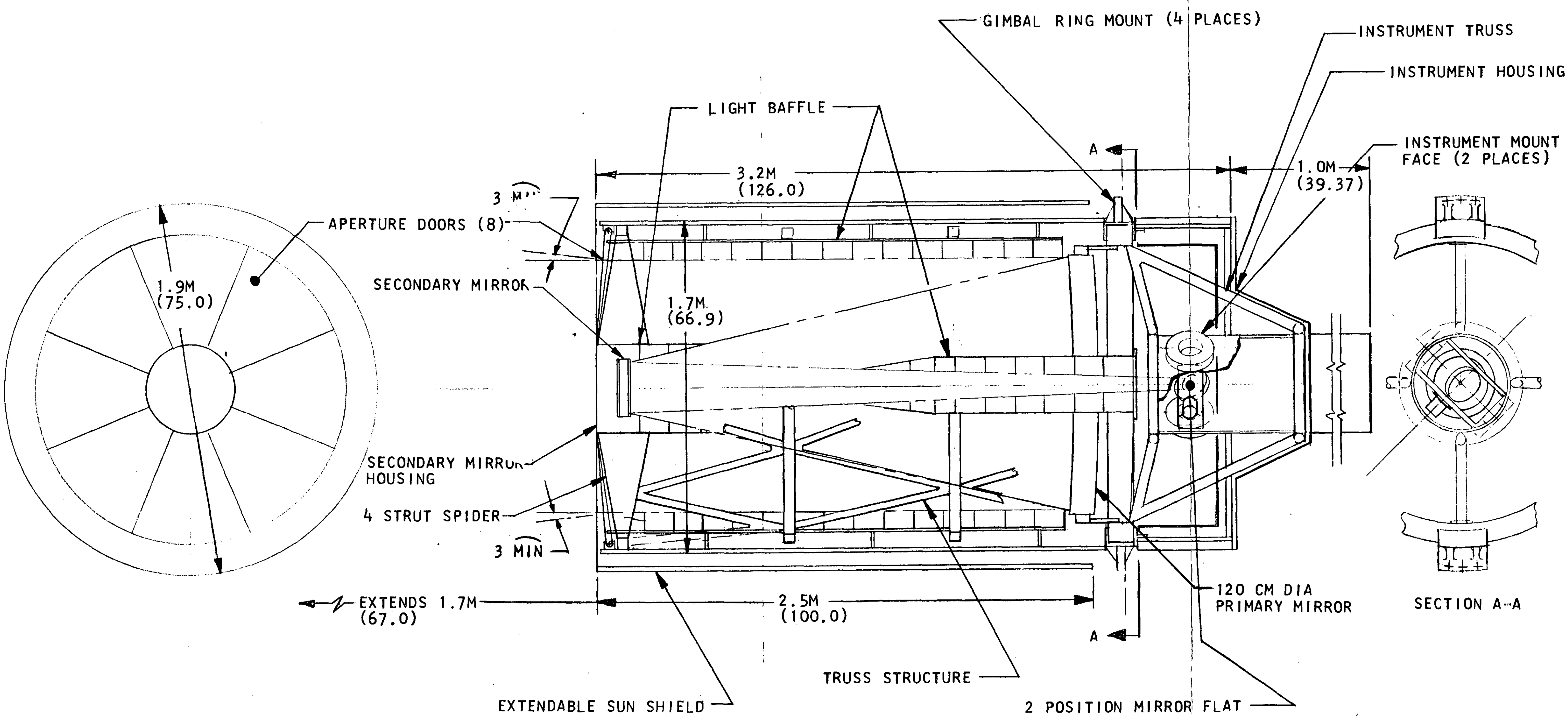

Figure IV-19 Stratoscope III (120 cm)

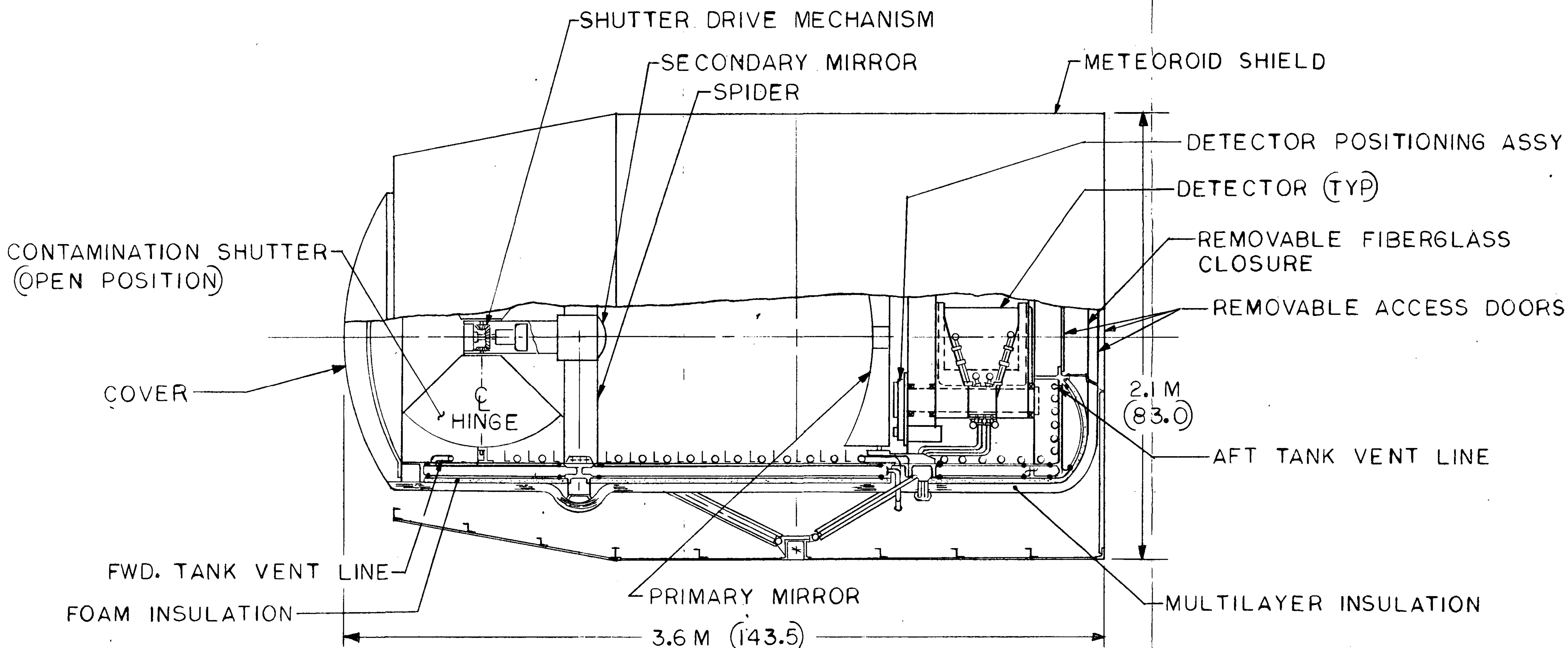

Figure IV-20 Infrared Telescope

b. Airlock/Hangar Concept

1) Photoheliograph - Itek, under separate contract to NASA/MSFC, has studied a 1.5 meter photoheliograph for the Large Solar Observatory, a 1.0-meter telescope for balloon use, and another 1.0-meter version for Shuttle Sortie flights (Fig. IV-21). The figure shows the results of repackaging the instruments and locating them at the aft end of the telescope. The entire instrument compartment of this concept must be pressurizable for shirtsleeve access. A small, remotely operated door is used to close the image hole in the pressure bulkhead during pressurization. The compartment structure is sized to allow shirtsleeve access to the entire instrument complement. The interface to the Sortie Lab airlock is located at the aft end of the structure. A thermal/meteoroid barrier door covers the opening at the interface while the telescope is in operating mode.

2) Stratoscope III - The airlock/hangar concept of the stratoscope III (Fig. IV-22) represents a modification of the baseline telescope. The pressurizable instrument compartment shown is essentially the same as shown on the photoheliograph. However, with a Cassegrain system, the image is brought to the instruments through a hole in the secondary mirror, which requires using a different door assembly to seal the image hole in the pressure bulkhead.

3) Infrared Telescope - Extensive modifications were made to the baseline telescope to achieve compatibility with the airlock/hangar access concept. For the baseline design, the instruments were located within the very cold confines of the wraparound tank structure. Since the temperatures involved with this approach are far too low for man to tolerate in shirtsleeves, the instrument compartment was relocated to the outside of the tank, as shown in Figure IV-23. The cylindrical structure of the pressurizable compartment is made of fiberglass laminate in order to minimize heat losses and the resulting high neon boiloff rates. Sealed foam insulation is attached to the inside surfaces of the compartment to prevent condensation of moisture on the cold surfaces.

No provision is included for remote positioning of instruments at the focal plane, since this would be accomplished during the access periods. Because the instruments are no longer operating in a very cold environment, a cryostat was added to provide cooling.

The instruments, although cryogenically cooled, can be packaged to be handled by a man in shirtsleeves. However, a major problem that needs further study is associated with condensation and freezing of moisture on the cold surfaces in the vicinity of the door in the pressure bulkhead. Another problem involves the need for disconnecting and reconnecting the cryogen lines between the cryostat and the instrument.

c. Folded Optics Concepts - The folded optics configurations represent modifications to the airlock/hangar designs described above. The major change was relocating the instrument complements inside of the Sortie Lab. A configuration for the IR telescope in the mechanical gimbal is not shown (Fig. IV-23), since the requirement for on-orbit access to this telescope was deleted before definition of the mechanical gimbal.

1) Photoheliograph - This telescope incorporates a second fold mirror (located in the light tube between the first fold mirror and the instruments) that deflects the image through the bearing into the Sortie Lab. In the gas bearing concept (Fig. IV-24). this mirror is fixed, because the telescope and instrument package move together as a unit. However, the mechanical gimbal concept (Fig. IV-25) requires that this mirror translate along the axis of the light tube, and tilt to keep the light beam fixed with respect to the instruments. Internal image motion compensation (IMC) is required for both the gas bearing and mechanical gimbal concepts. The primary differences in the IMC are due to the fact that the gas bearing will provide a base stability of approximately 0.1 $\widehat{\text{sec}}$, while the mechanical gimbal will provide a base stability of approximately 1.0 $\widehat{\text{min}}$.

In both concepts, the instrument complement is rigidly mounted to the telescope support structure. The support structure and the removable cover allow the instruments to operate in a vacuum without having a window in the path of the image beam. If desired, the instruments may be operated under pressure by moving a pressure window (located in the support structure) into position. With the window in position, the cover may be removed for access to the instruments. Various instrument controls and monitoring devices may be mounted on the housing to provide "hands-on" operations.

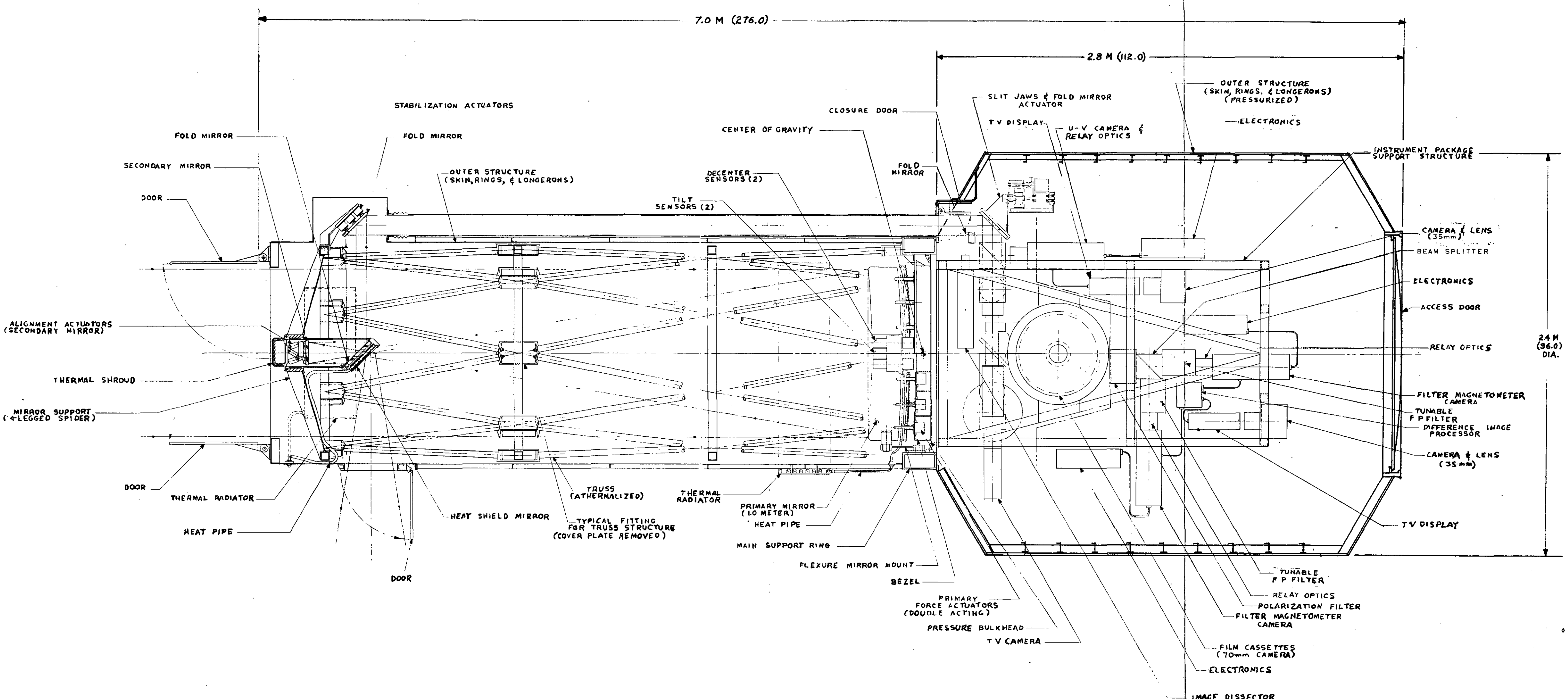

Figure IV-21 Photoheliograph, Airlock/Hangar Concept

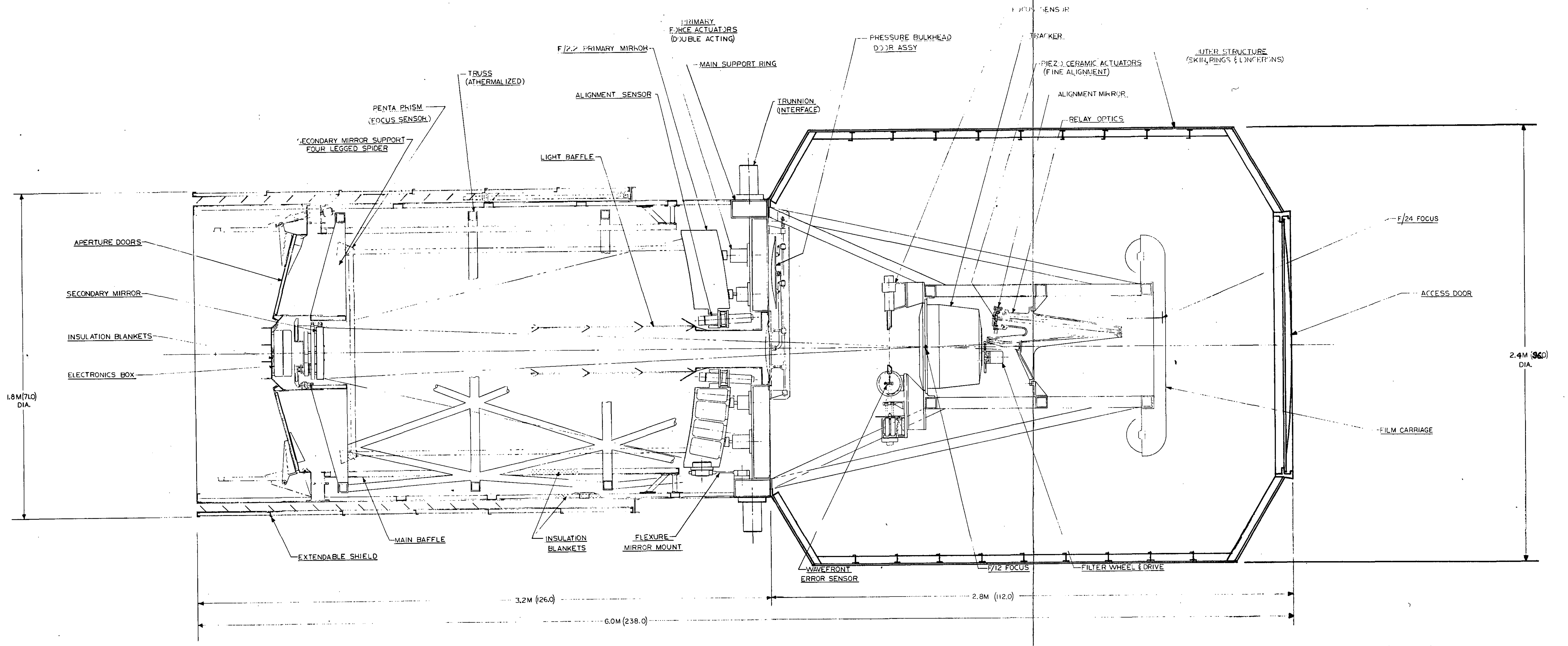

Figure IV-22 Stratoscope III, Airlock/Hangar Concept

IV-91 and IV-92

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

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2) Stratoscope III - The fold mirror in this telescope is located on the centerline of the telescope and remains fixed for the gas bearing concept (Fig. IV-26). For the mechanical gimbal concept (Fig. IV-27), the mirror need not translate, but must be tilted. Since the mirror is located at the intersection of the gimbal axes, a 45.8-centimeter (18-in) long slot must be provided through the telescope structure to allow passage of the image to the instruments. As in the case of the photoheliograph, IMC is required for both concepts. Instrument mounting and access features are identical to those described for the photoheliograph.

3) Infrared Telescope - The fold mirror of this telescope is located on the centerline of the telescope and remains fixed for the gas bearing concept (Fig. IV-28). No IMC is required for this telescope on the gas bearing. Since the instruments for this telescope must operate at cryogenic temperatures, a cryostat is provided. No instrument cover is provided since only one instrument will be operating at any time. The instrument case must be pressure-tight to allow operation of the detector in a vacuum. When instrument replacement is desired, the pressure window located in the support structure is moved into position. This configuration involves the need to disconnect and reconnect the cryogen lines between the cryostat and the instrument.

d. Mass Properties - Summary weight statements for the telescope configurations developed for on-orbit access are presented in Tables IV-22 and IV-23. The weight statements are presented in the form of removals and additions to the baseline telescopes. For the gas bearing and mechanical gimbal concepts, the telescope instruments are included in the weight statements (para 5) for the concepts.

4. Telescope Performance Analyses

Telescope performance analyses were conducted to provide a comparison between the baseline telescopes and the telescopes designed for the gas bearing access concept, which involves bringing the telescope image into the Sortie Lab. Performance of the telescopes in the airlock/hangar concept is the same as the baseline telescopes. Similarly, performance of the photoheliograph and stratoscope III in the mechanical gimbal concept will be essentially the same as for the gas bearing concept. The requirement for on-orbit access to the IR telescope instruments was deleted during the study, but results of the investigation conducted up to this point in time, are included.

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Table IV-22 Summary of Telescope Weights for Hangar Concept

IR Telescope [kg (lb)]				
Baseline IR Telescope (Ref 1)			1988.1	(4383)
Remove From Baseline:			-796.5	(-1756)
Instruments	103.9	(229)		
Instrument Mech	22.7	(50)		
Structure and Insulation	320.7	(707)		
Neon	349.3	(770)		
Add:			+420.9	(+928)
Structure and Insulatiuon	200.5	(442)		
Heaviest Instrument	61.7	(136)		
Neon	158.7	(350)		
Modified Telescope			1612.5	(3555)
Alternative Instrument (In Sortie Lab)			+42.2	(+93)
Modified Telescope with Alternative			1654.7	(3648)
Photoheliograph [kg (lb)]				
Baseline Photoheliograph (Ref 1)			997.9	(2200)
Remove From baseline:			-142.9	(-315)
Instrument Housing	133.8	(295)		
Trunion Ring	9.1	(20)		
Add:				
Hangar			+450.9	(+994)
Forward Bulkhead	52.2	(115.0)		
Aft Bulkhead	61.7	(136.0)		
CYL	127.0	(280.0)		
Insulation	41.7	(92.0)		
Meteoroid Bumper	34.5	(76.0)		
Trunion	10.4	(23.0)		
Internal Frame	93.9	(207.0)		
Door and Mech	27.2	(60.0)		
Ins and M/P on Door	2.3	(5.0)		
Modified Telescope			1305.9	(2879)
Stratoscope III [kg (lb)]				
Baseline Stratoscope III (Ref 1)			1792.1	(3951)
Remove From Baseline:			-158.3	(-349)
Instrument Compartment				
Compartment	124.7	(275)		
Insulation	10.9	(24)		
Misc.	22.7	(50)		
			1633.8	(3602)
Add:				
Hangar (Same as PHG)			+450.9	(+994)
Modified Telescope			2084.7	(4596)

Table IV-23 Summary of Telescope Weights for Gas Bearing and Mechanical Gimbal Concepts

IR Telescope [kg (lb)]		
Baseline IR Telescope (Ref 1)		1988.1 (4383)
Remove From Baseline:		-947.5 (-2089)
Instruments	103.9 (229)	
Instrument Mech	22.7 (50)	
Structure and Insulation	320.7 (707)	
Neon	349.3 (770)	
Cooler	61.2 (135)	
Helium	10.0 (22)	
Frame	66.2 (146)	
Meteoroid Frames	13.6 (30)	
Add:		+383.8 (+844)
Main Frame	111.1 (245)	
Bulkhead	84.4 (186)	
Foam Insulation	3.6 (8)	
Super Insulation	4.0 (9)	
Tank Screen	1.4 (3)	
Heat Ex. Tubes	2.3 (5)	
Neon	158.7 (350)	
Fold Mirror	9.1 (20)	
Fold Mirror Supp.	8.2 (18)	
Modified Telescope		1423.4 (3138)
Photoheliograph [kg (lb)]		
Baseline Photoheliograph (Ref 1)		997.9 (2200)
Remove From Baseline:		
Instruments and Housing		-351.5 (-775)
Add:		
Attach Structure		+22.7 (+50)
Modified Telescope		669.1 (1475)
Stratoscope III [kg (lb)]		
Baseline Stratoscope III (Ref 1)		1792.1 (3951)
Remove From Baseline:		-919.4 (-2027)
Instrument Compartment	124.7 (275)	
Insulation	10.9 (24)	
Electrical	63.9 (141)	
Instruments	699.0 (1541)	
Misc.	20.9 (46)	
Add:		+77.1 (+170)
Bulkhead	17.2 (38)	
Insulation	5.4 (12)	
Attach Structure	9.1 (20)	
Fold Mirror Install.	45.4 (100)	
Modified Telescope		949.8 (2094)

a. Wavefront Error Effects - One extra mirror is needed to convert the conventional photoheliograph, stratoscope III, and IR telescope optics so that their focal surfaces are inside the Sortie Lab. If this mirror was absolutely flat and smooth, then it would not affect wavefront error and so would not affect optical resolution. Unfortunately, some residual curvature inevitably is found in a "flat"--this curvature introduces some astigmatism in the folded image.

1) Photoheliograph - The 1-meter wavefront error budget for the photoheliograph (developed for NASA/MSFC) came to 0.10 λ rms at 0.63 μm. A fold mirror to bring the focal surface into the Sortie Lab will have an error of approximately 0.01 λ rms. A smaller number might be achieved, but this is already near the limits of test accuracy. When the 0.10 λ rms photoheliograph is rss'd with the 0.01 λ rms fold mirror, the result is an increase of about 0.0005 λ rms in the system. Figure IV-29 shows how system modulation transfer (MTF) varies with wavefront error (a 30% obscuration, and zero motion, were assumed). From this figure it is possible to relate angular resolution to wavefront error (Fig. IV-30). Resolution was defined at 30% modulation because so many astronomical scenes are of low contrast. The flat is seen to introduce less than 1% loss in resolution due to wavefront error.

2) Infrared Telescope - The baseline IR telescope wavefront error has been estimated at 0.64 λ rms at 0.63 μm (or 0.1 λ rms at the design wavelength of 4 μm). This large error was assumed because of the severe thermal environment. In the case of a small fold mirror, however, it should be possible to keep thermal gradients under control so that the system performance should not be further degraded.

3) Stratoscope III - The stratoscope III wavefront error budget sums to 0.050 λ rms. This is an improvement over the photoheliograph because the optics are simpler, the thermal environment is less rigorous, and a desire to duplicate the LST budget was assumed. If it is again assumed that a fold mirror introduces 0.01 λ rms, then the system error increases 0.001 λ rms. From Figure IV-30, the resolution loss is less than 2%.

Adding a fold mirror to any of the three baseline telescopes does not introduce enough wavefront error to degrade resolution significantly.

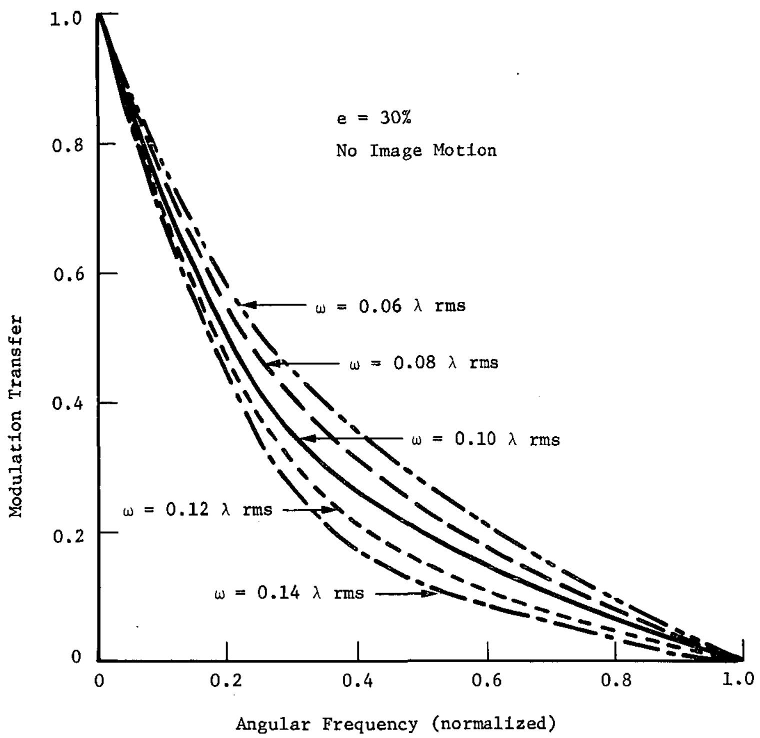


Figure IV-29 Effect of Wavefront Error on MTF

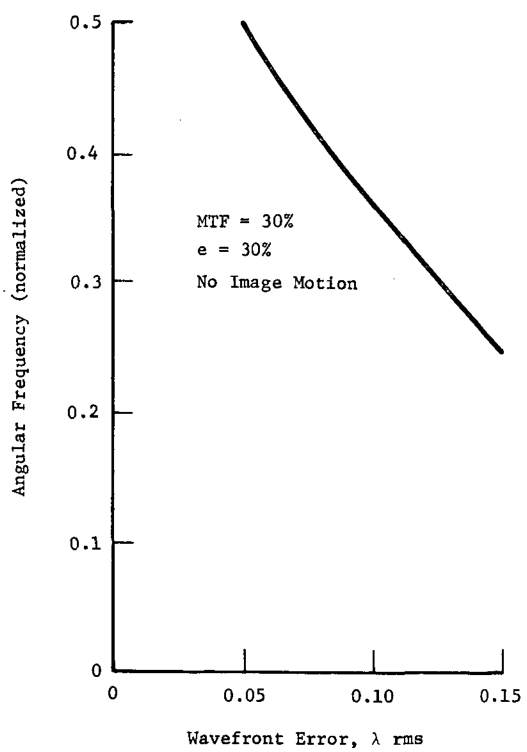


Figure IV-30 Normalized Angular Resolution vs Wavefront Error *b. Obscuration Effects* - Having determined that the fold mirror used to bring the focal surface into the Sortie Lab introduces a negligible wavefront error, the obscuration of the aperture and the resulting system performance must now be considered. Angular resolution is degraded by wavefront error, obscuration, and image motion. It was assumed that the fold mirror does not affect image motion.

In this analysis a gas bearing gimbal and a fold distance of 1.75 meters (68.9 in) (Fig. IV-31) were used. Due to the addition of a cold stop to the IR instruments, this distance was later increased to 2.0 meters (78.7 in). Performance was not recalculated because on-orbit access requirements for the IR telescope were deleted, and the photoheliograph and stratoscope III are not sensitive to this change.

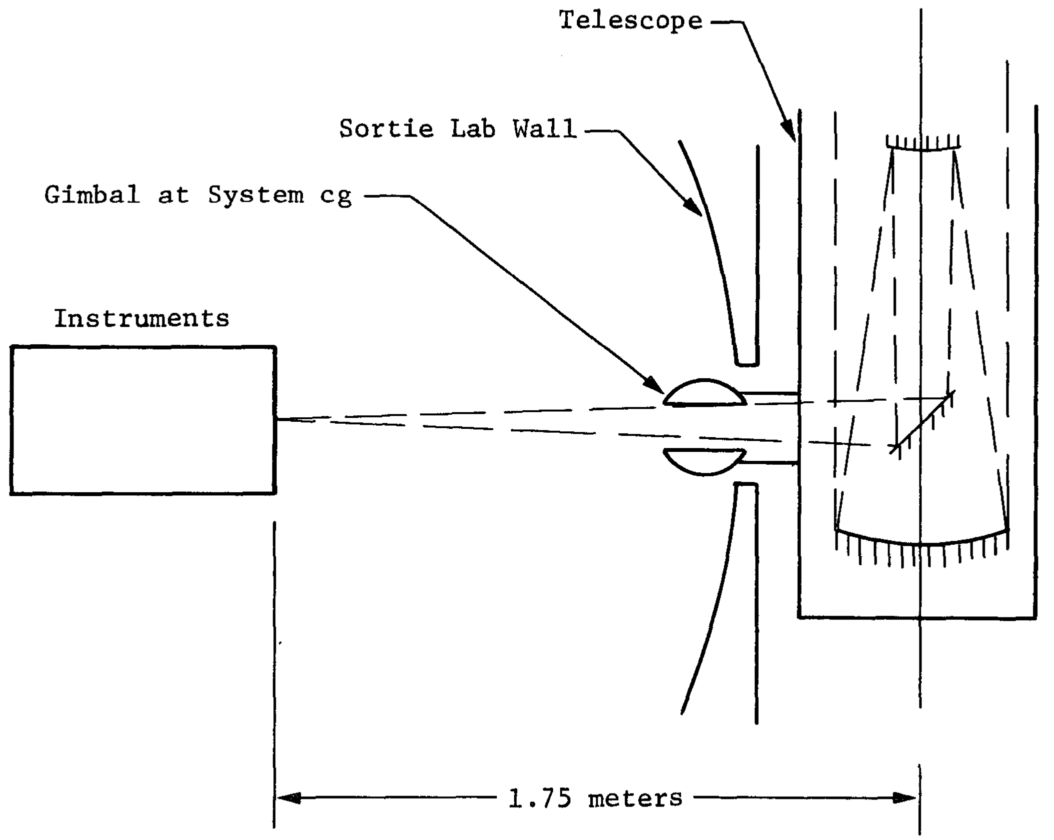
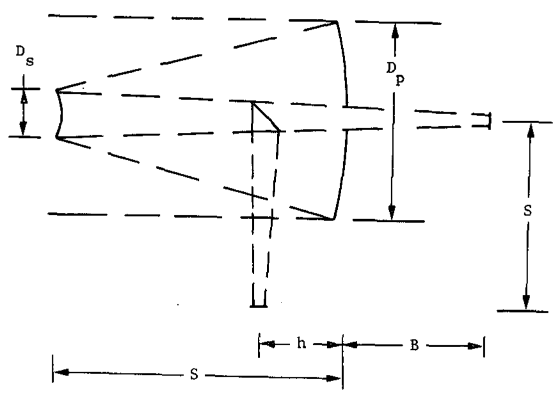


Figure IV-31 Gas Bearing Gimbal at System Center of Gravity

To achieve highly stable pointing of the telescope, the system must be gimbaled at its center of gravity (cg). This dictates that the fold mirror must be at the telescope cg, since the system cg is on a line between the cg of the telescope and the instruments. If the fold mirror were at some other location, then the tunnel through the gimbal would have to be off center and the gimbal would be enlarged.

With the location of the fold mirror fixed at the telescope cg, and the fold distance fixed by considerations of telescope diameter, gimbal size, and Sortie Lab requirements, the vertex back focus is no longer a variable (Fig. IV-32). However, vertex back focus can influence obscuration and, therefore, telescope resolution. If too much resolution is lost by folding the focal surface to the side, the fold mirror must be moved and counterweights added to the telescope, or changes must be made to basic parameters, such as the focal lengths of the primary mirror and telescope. These changes will impact field of view, plate scale, manufacturability, and tolerance to misalignment.



$B = g - h$

$S = (f - B)/(m + 1)$

$D_s = D_p\ (B + P)/(f + P)$ $\qquad \therefore e_s \equiv D_s/D_p = (B + P)/(f + P)$

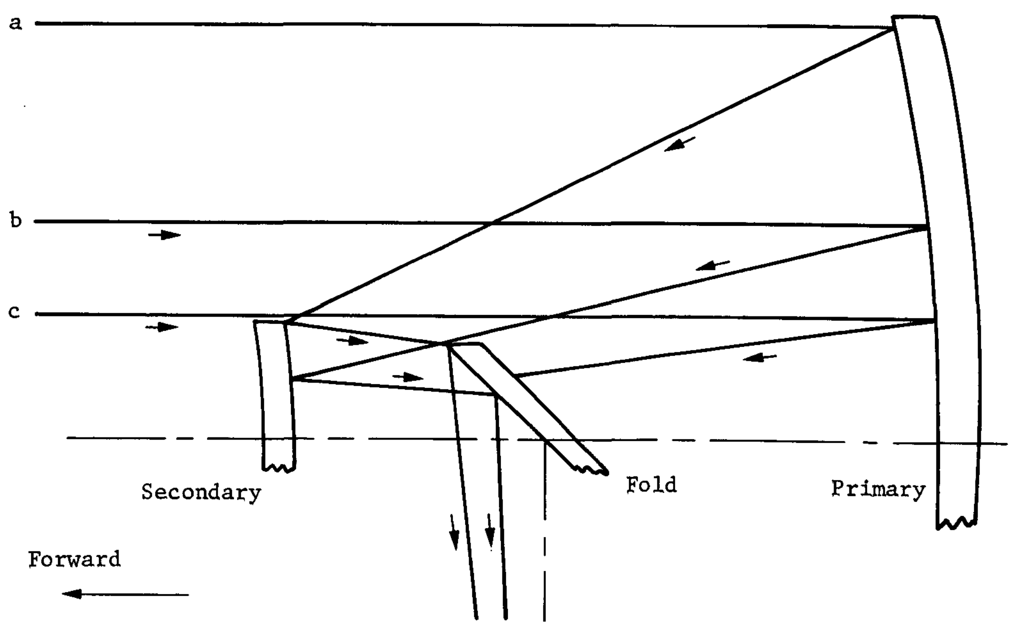
Where:

- e_s = Obscuration of secondary mirror;
- D_p, D_s = Dimeters of primary and secondary mirrors;
- B = Vertex back focus;
- f = Focal length of system (negative in a Gregorian telescope);
- m = Magnification $\equiv$ f/p;
- P = Focal length of primary mirror;
- g = Fold distance;
- h = Location of fold mirror.

Figure IV-32 Basic Two-Mirror Telescope Relations

Figure IV-22 shows how obscuration by the secondary mirror is related to vertex back focus. If there were negligible field of view, then this would be the system obscuration as well. However, the photoheliograph, IR telescope and stratoscope III all have high-quality data fields of view on the order of 1.45 mrad to 1.75 mrad (5 to 6 $\widehat{\text{min}}$) in diameter, so that a baffle system is needed, and the obscuration will be increased a few percent. If off-set guiding is to be used on stratoscope III, the field of view must be about 8.72 mrad (30 $\widehat{\text{min}}$) and the obscuration is increased substantially. Unfortunately, there are no simple formulae for calculating baffle obscuration so that educated guesses, graphical analyses, or computer programs are required.

The fold mirror itself can contribute to obscuration if it is placed so far forward that it blocks light converging from the primary toward the secondary mirror (Fig. IV-33). This problem has been investigated by graphical analysis.



Note: 1. Rays a and b can pass to the focus.
2. Ray c is intercepted by the fold mirror, which is too far forward.
3. The obscuration is therefore b/a rather than c/a. The solution is to move the fold closer to the primary mirror.

Figure IV-33 Obscuration by Fold Mirror

Obscuration and resolution changes for each of the three telescopes are discussed in the following paragraphs.

1) Photoheliograph - The airlock/hangar/photoheliograph is the 1.0-meter f/3-f/40 system shown in Figure IV-21. The field of view is 1.75 mrad (6 $\widehat{\text{min}}$). Because this is a Gregorian telescope, the system focal length and magnification are negative (Fig. IV-32).

The fold mirror could be arranged to take the light out the same side as the off-axis light tunnel or out the opposite side (Fig. IV-34). The vertex back focus (and therefore obscuration) and tube length are less in the first case, but the mounting to the gimbal becomes more complicated, both structurally and dimensionally. Both fold options were investigated, the results are shown in Figure IV-35. Because the cg will be near h=1.0 meter (39.4 in), the fold mirror appears to introduce some extra obscuration. However, the obscuration is in fact set by the structure supporting the secondary mirror, and is approximately 30%.

The conclusions reached are that the fold mirror can be moved over a wide range without introducing excess obscuration, and that, as far as image quality is concerned, the fold may be away from or through the tube. Some other factors affecting choice of fold direction will be discussed later.

2) Infrared Telescope - The airlock/hangar IR telescope is the 1.0-meter f/1.5-f/10 system described in Reference 1. The cg of the folded version has been estimated to be at h=0.6 meter (23.6 in) in front of the primary. Guiding will be done with an auxiliary telescope, so that the field of view is only 1.45 mrad (5 $\widehat{\text{min}}$).

Figure IV-36 shows how the location of the fold mirror affects obscuration. The 25% f/1.5-f/10 telescope obscuration is increased to 35% with the mirror at the cg h=0.6 meter (23.6 in). From Figure IV-37, the resulting resolution loss is about 6%. This figure was derived from MTF analysis, and includes the effects of 0.1 λ rms wavefront error at 4.0 μm, 0.0015 mrad (0.4 $\widehat{\text{sec}}$) rms guide error, and a 0.1-millimeter (0.0039-in) sensor. The optics themselves suffer a 30% resolution loss, but the system loses only 6% because it is sensor limited. For this reason the folded system would not benefit as much from improvements in the sensor state of the art as would the unfolded system.

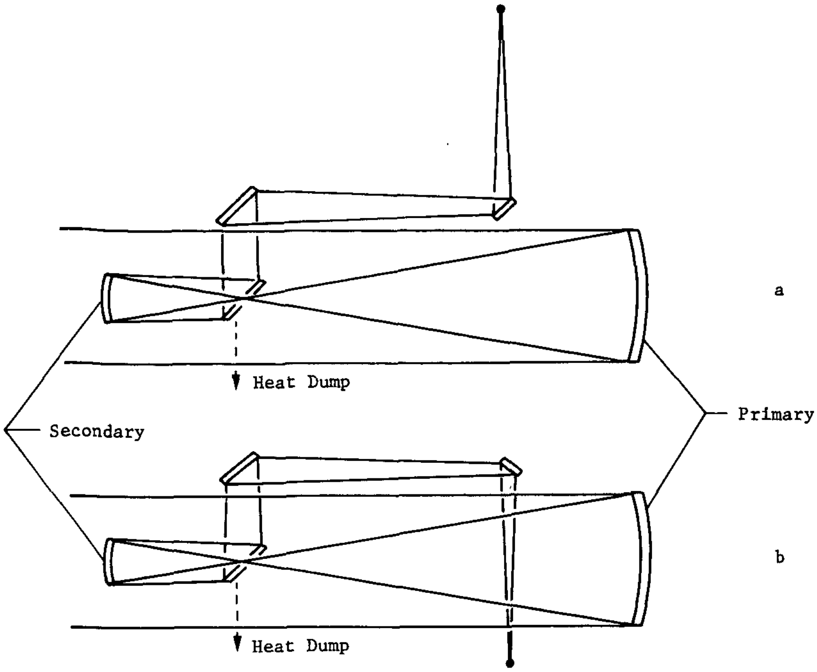


Figure IV-34 Two Fold Options for Photoheliograph

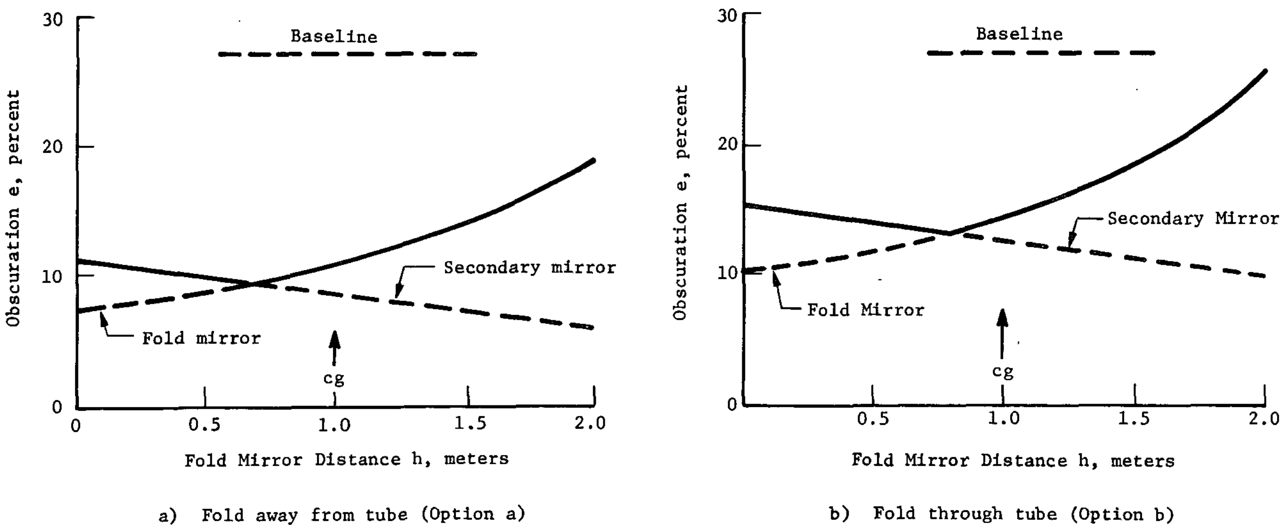


Figure IV-35 Obscuration Analysis for Folded Photoheliograph (1-meter f/1.5 - f/10. g = 1.75 meters)

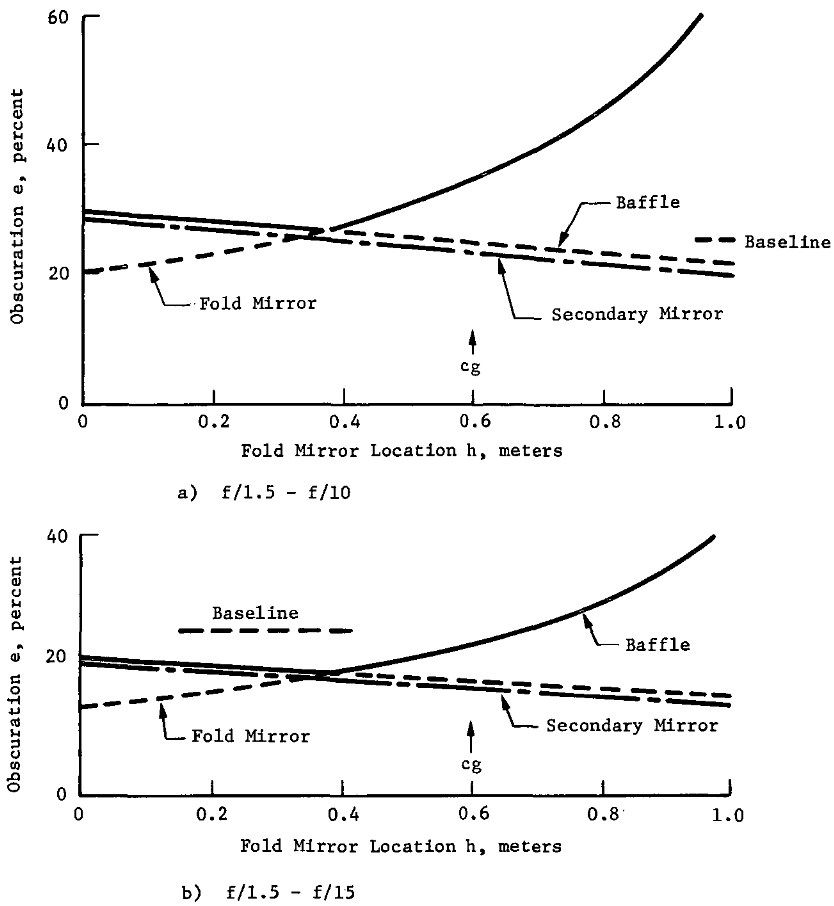


Figure IV-36 Obscuration Analysis for Folded IR Telescope

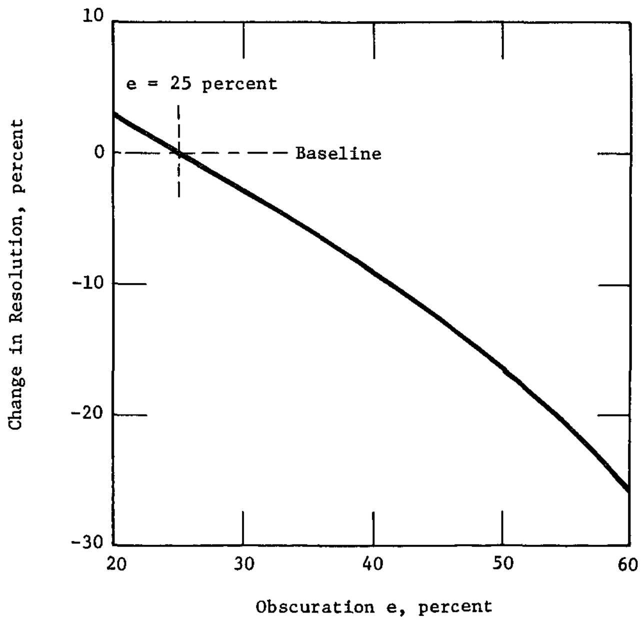


Figure IV-37 Change in Resolution of IR Telescope vs Obscuration

Figure IV-36 shows that an f/1.5-f/15 telescope could maintain the baseline obscuration of 25%. However, this causes a 33% loss in field of view, and the tolerance to misalignment of the secondary mirror is 3.4 times worse. It is not possible to achieve 25% obscuration in a folded f/10 system by changing primary f/number, or by moving the cg or locating the fold mirror off the cg.

An investigation was made to determine the possibility of reducing obscuration to 25% by changing the fold distance from 1.75 meters (68.9 in) (g in Fig. IV-32). Figure IV-38 shows that the distance must be reduced to about 1.3 meters (51.2 in). This is insufficient to include the telescope radius, the gas bearing, and space required in the Sortie Lab.

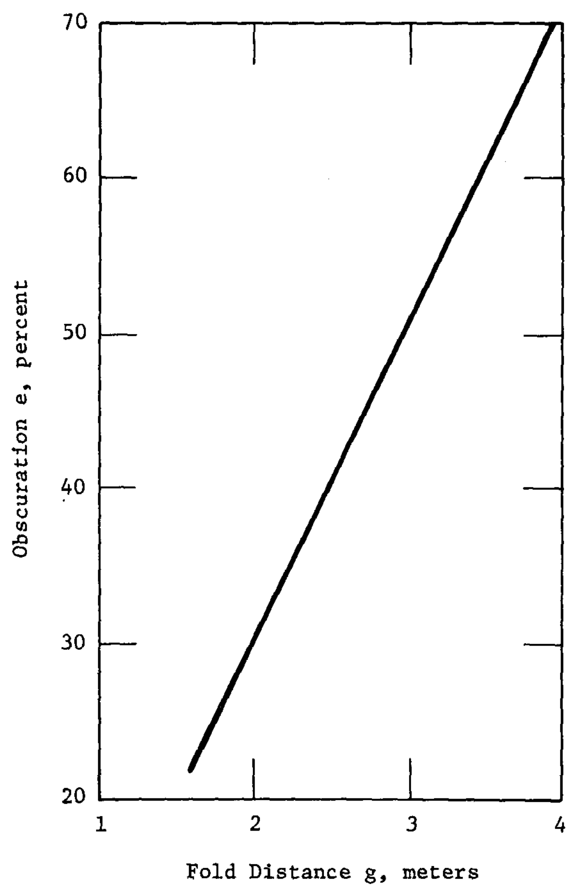


Figure IV-38 Effect of Fold Distance on Baseline IR Telescope

This leaves two feasible alternatives: an f/1.5-f/10 telescope with 6% loss of resolution; or an f/1.5-f/15 telescope with 33% loss of field of view, and tighter tolerancing. The tighter tolerances may make it impossible to maintain image quality at reasonable cost; therefore, it was concluded that the f/1.5-f/10 should be retained as baseline for the folded system.

3) Stratoscope III - The baseline stratoscope III is the 1.2-meter f/2.2-f/12 scaled-down LST. Guiding will be done with off-set sensors and a 13.08 mrad (45 $\widehat{min}$) guide field will be required to ensure high probability of finding adequately bright stars in any part of the sky. LST needs only 6.97 mrad (24 $\widehat{min}$) but has a larger aperture so it can see objects that are two magnitudes fainter. Baseline obscuration is 34% (Currently 30% in LST).

From Figure IV-39, it can be seen that the fold mirror can be at the center of gravity without increasing obscuration. The cg is estimated to be approximately 0.5 meter (19.69 in.) in front of the primary mirror.

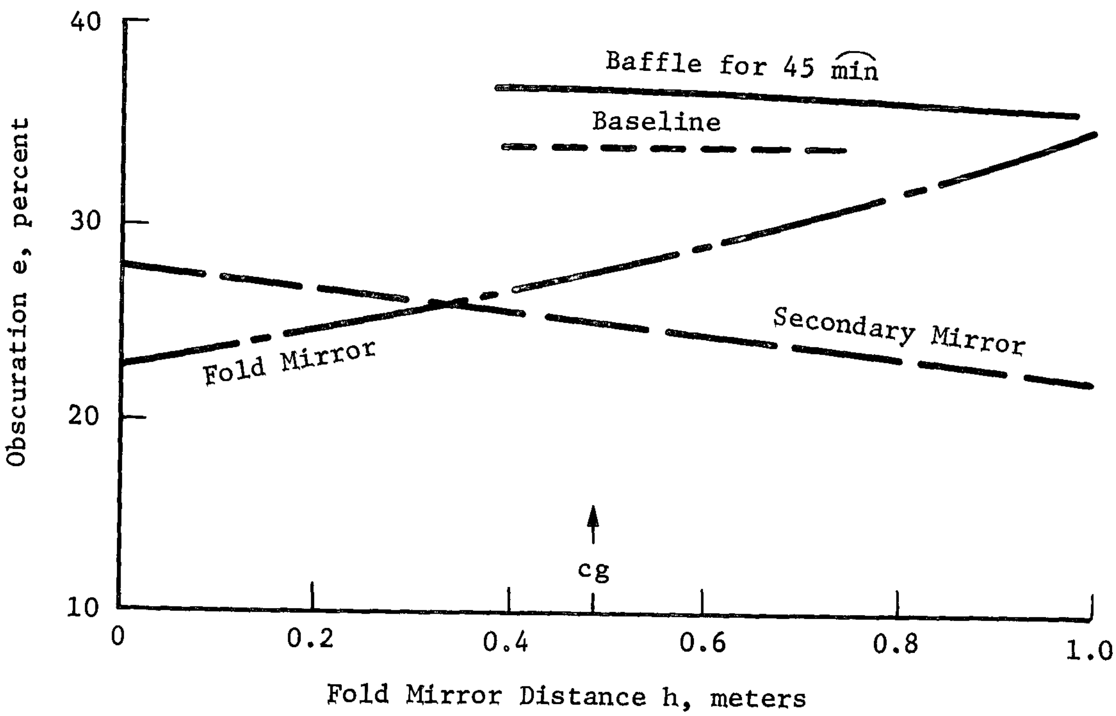


Figure IV-39 Obscuration Analysis of Folded Stratoscope III [1-meter, f/2.2 - f/12. 45-$\widehat{min}$ (13.1 mrad field. g = 1.75 meters.)]

c. Other Considerations - Considerations that could impact the decision to fold the focal surface into the Sortie Lab are discussed in the following paragraphs.

One problem common to both the IR telescope and the stratoscope III is that of diffuse reflections off the outside of the baffle (Fig. IV-40). (In the case of the photoheliograph there is no conic baffle because of the field stop at the primary focus). This diffuse reflection can perhaps be controlled with knife edges on the baffle. (The University of Arizona is developing methods for analyzing such baffle structures.)

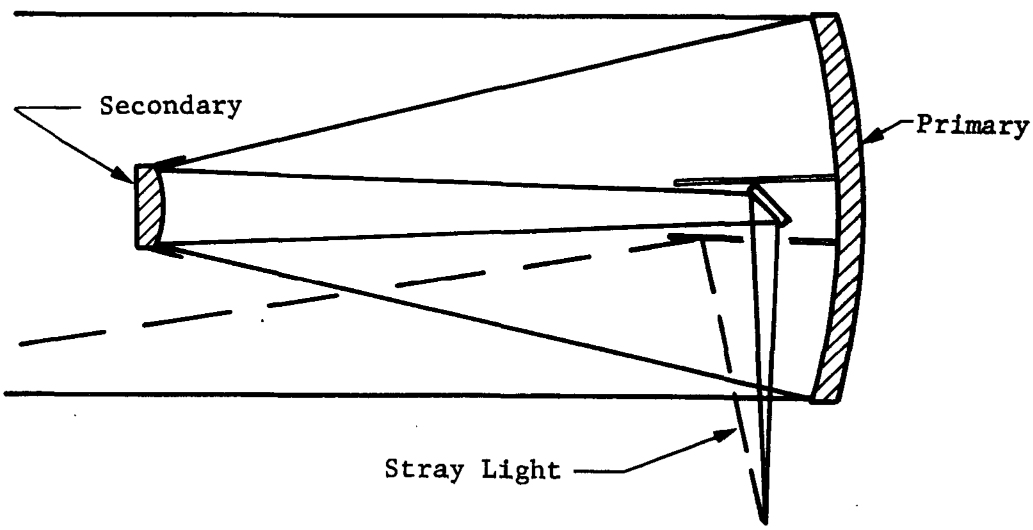
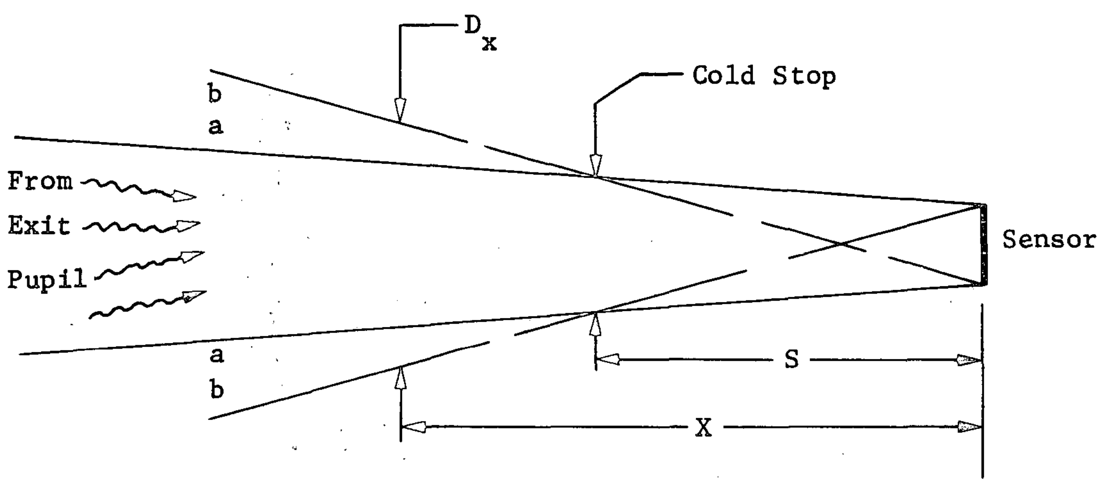


Figure IV-40 Diffuse Reflection off Baffle in Folded System

Two options for folding the focal surface of the photoheliograph were previously discussed (Fig. IV-34). If the fold is through the tube (option b) then the heat dump (solar image at the primary focus) is towards the Sortie Lab and clearance must be allowed for the external mirror shown in Figure IV-21. If option a is chosen, the external mirror can perhaps be eliminated--it is needed only if the heat dump could pose a problem to the Shuttle or other instruments.

The cryogenically-cooled IR telescope has a special problem when it is reconfigured to bring the focal surface into the Sortie Lab. This is because any warm structure that can be seen by the sensor, directly or by reflection, will generate photoelectrons that degrade the signal-to-noise ratio. In the unfolded IR telescope, the image is brought through a warm gimbal that could get in the detector's field of view.

Figure IV-41 shows how the problem comes about.



Note: **For 1-meter, f/1.5 - f/10 IR Telescope with 5 min field of view (all units in meters).**
D_x = (.0951 + .0292/S) X -0.0146.

Figure IV-41 Problem of Warm Structures in IR Telescope Sensor Field of View

No structure is allowed in cone aa if vignetting is to be avoided. In most systems this would be the only consideration; however, in the IR telescope there must be no warm structures within cone bb. The diameter, D_x, is a function of s (which should be as large as possible) and x (which should be as small as possible). In the case of the 1.0-meter f/1.5-f/10 IR telescope with 1.30 mrad (5 $\widehat{\text{min}}$) field of view, if the cold stop is at s = 0.2 meter (7.88 in.) and the gimbal is at x = 0.35 meter (13.78 in.), the hole in the gimbal must be D_x = 0.07-meter (2.75 in). If the telescope mounting to the gimbal at x - 1.0-meter (39.37 in) involves warm structures, then it must have a clear opening in excess of 0.26-meter (10.24 in) diameter.

There are at least two methods of avoiding this problem; however, each method presents difficulties of its own. One method would be to extend a cryogenic sheath into the gimbal, and therefore effectively extend the cold stop distance, s. This would probably be difficult to service and could create a large thermal load. The other method is to use relay optics as a field lens. These must be all reflecting so that several mirrors are needed, and some extra wavefront error will result.

d. Summary - In the preceding paragraphs, some of the problems that arise when the focal plane of a telescope is folded into the Sortie Lab, were analyzed. The fold gives maximum manned access to the focal instruments, but no access to the telescope. In these analyses no compelling optical arguments against this reconfiguration of the telescopes were found, though problems were found that will result in slightly poorer performance, a little more difficulty in achievement, and a slightly higher cost.

5. Configuration Analysis

The telescope designs for the concepts discussed below are described and analyzed in the preceding sections of this report. This section describes the major features and problem areas of the shirtsleeve on-orbit access accommodation concepts, and presents mass properties data for the concepts. A summary of the baseline concept is included for comparison. Sketches of the three on-orbit access concepts are shown in Figure IV-17, along with the baseline concept, which does not provide shirtsleeve on-orbit access.

a. Baseline Concept - The baseline concept (Ref 1) uses the short Sortie Lab with a single telescope mount attached to the pallet. The baseline includes two mounts; however, only the forward mount is shown. This allows a valid comparison to be made between the baseline and the on-orbit access concepts. The mount shown deploys the telescope out of the payload bay and provides hemispherical viewing capability as well as fine pointing capability with a stability of 0.1 sec. Four CMGs, mounted to the pallet, are used for Shuttle orbiter orientation and stabilization. Because no shirtsleeve on-orbit access to the telescope is provided activities such as monitoring, adjustments, filter selection, and instrument changes are accomplished by remote control from the C&D panel in the Sortie Lab. Inflight maintenance and repair cannot be accomplished.

b. Airlock/Hangar Concept - This concept provides for periodic on-orbit access to the instrument compartments of the telescopes. Figure IV-42 shows the airlock mounted to a bulkhead attached to the aft end of the Sortie Lab. Since this concept does not intrude into the Sortie Lab, a short Sortie Lab, 4.72 meters (186 in.) in length may be used. The telescopes are shown on the pallet, supported by a mount and gimbal assembly very similar to the common mount and gimbal assembly defined in Reference 1. When operating, the telescope is deployed out of the payload bay; when access is desired, it is returned to the launch position shown. The telescoping airlock is extended to interface with the pressurizable instrument housing or hanger, on the telescope, and the latches are engaged across the interface. At this time, the door in the telescope pressure bulkhead is closed by remote control from the Sortie Lab and pressurization begins. As the pressurization proceeds, the screwjacks are actuated to provide tension across the interface, which alleviates the large loads that would otherwise act on the telescope mount. These loads are considerably higher than those imposed on the mount during Shuttle launch and return to Earth. The telescoping airlock design is based on an expandable structure designed, fabricated, and ground tested by Martin Marietta under contract to the Air Force Materials Laboratory (Ref 9).

The major anticipated problem area in this concept involves the environment to which the instruments are exposed. Pressurization of the instrument compartment for shirtsleeve access requires introduction of the warm and relatively moist atmosphere of the Sortie Lab, which could result in condensation of cool surfaces. When the telescope is in the operating position, the thermal environment may be quite different, causing the optical assemblies to change geometry. A special problem is associated with the IR telescope, which has cryogen-cooled instruments. The instruments can be designed with acceptable touch temperatures for handling, and it is assumed that an instrument would only be removed when it is to be replaced with another unit. However, the replacement unit should be cooled to near operating temperature to minimize telescope downtime. This requires exclusion of moisture from the cold surfaces of the unit until the telescope is again ready to operate. The instrument mounting surfaces and the door assembly on the pressure bulkhead must be kept warm until the atmosphere has been released. Another contamination problem will occur if this atmosphere is dumped overboard.

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While the problems highlighted above should not prove to be insurmountable, each one will require careful consideration during the early stages of development of this concept.

c. Gas Bearing Concept - Bringing the telescope image into the Sortie Lab provides continuous access to the instruments for monitoring and adjustment, even during observations. However, when the instruments operate in a vacuum in order to prevent passing the image through a window, direct access for instrument replacement requires suspending observations. Figures IV-24, IV-25, and IV-27 show the three intermediates class telescopes mounted on a gas bearing similar to the one used in the Ames C141 IR Telescope Program. This bearing is capable of providing a base stability of approximately 0.1 $\widehat{sec}$, but gimbal travel is limited to 0.0436 radian (± 2.5 deg) about the three orthogonal axes of the bearing. The centerline of the bearing is offset below the centerline of the Sortie Lab in order to accommodate any of the telescopes within the payload envelope of the Shuttle orbiter. Counterbalancing is necessary in all cases since the cg of the entire gimbaled mass must lie at the center of the spherical gas bearing. In addition, the IR telescope requires a movable counterweight to compensate for neon boiloff from the telescope cryogen tank. A long Sortie Lab, 7.77 meters (306 in.) in length, is required to accommodate the large instrument package within the Lab.

Several problem areas are inherent with the gas bearing concept. The first of these is the very limited gimbaling capability of the bearing, which requires maneuvering the Shuttle orbiter when it is desired to move from target to target. The thermal environment imposed on the instruments in this concept should be more constant than for the airlock/hangar concept, but active thermal control may still be required. The instruments for the IR telescope again cause special problems, similar to problems anticipated in the airlock/hangar concept. The movable counterweight system, required only for the IR telescope, will add complexity to this concept.

The gas supply and scavenging system required for this concept, is of special interest. Two types of systems were investigated: a blow down system that captures and holds the used gas; and a recycling system that filters and reuses the gas. Both systems retain the "used" gas rather than releasing it where it may become a source of contamination. Also, both systems require a ground-based gas supply and scavenging system if the bearing is to be operated at 1 g on the ground. Design parameters for the systems were: helium gas; 0.0018-inch bearing gap; 1.6 scfm, flow rate; Shuttle g level of 0.05; 2000 psi storage pressure (max); and a system mechanical efficiency of 20%.

The blowdown system regulates the 2000 psi storage tank pressure down to the proper level for the bearing. Pumps are used to take the scavenged gas to a 2000 psi holding tank. No filtering is required since the gas is not reused. This system requires approximately 3125 Watts of electrical power, and includes two large tanks, each capable of storing 95 cubic feet of helium at 2000 psi.

The recycling system stores makeup gas in a 5-cubic-foot tank at 2000 psi. From this tank, the helium passes through a regulator into a 3-cubic-foot plenum tank that feeds the gas to the bearing at a pressure of 45 psi. The scavenged gas is pumped through filters back to the plenum tank, and then reused. An estimated 1600 Watts of electrical power is required for this system.

Several variations to these systems were considered, but were rejected because of anticipated deficiencies. A blowdown system without scavenging capability would be a simpler system than the one described above, but dumping of the large amount of helium may cause a contamination problem. Reducing the gas bearing gap would reduce the gas flow rates, but would result in a more difficult bearing to fabricate.

The recycling system is recommended for this application, due to the lower power requirement, and the need for one relatively small low pressure tank rather than the two large tanks required for the blowdown system with scavenging capability.

d. Mechanical Gimbal Concept - This concept provides the same on-orbit access as the gas bearing concept, and the instruments are accommodated in the same manner as shown in Figures IV-24 and IV-26. The major difference lies in the fact that the gas bearing is replaced with a two-axis gimbal, capable of larger gimbal angles. As shown in Figure IV-12, ± 0.26 radian (± 15 deg) is provided in the pitch direction, and ± 0.87 radian (± 50 deg) is possible in roll. This means an important reduction in Shuttle maneuvering requirements. The mechanical gimbal will have a base stability of approximately 1.0 $\widehat{\text{min}}$. Along with eliminating the need for the gas supply and scavenging system, this concept simplifies the counterbalancing problem. The only requirement is to keep the telescope cg on the telescope pitch axis. A long Sortie Lab is required to accommodate this concept.

The instrument accommodations are the same for this concept as for the gas bearing approach, and the same problems can be anticipated. Some added complexity is incurred in the design of the telescopes for this concept. As discussed previously, the fold mirrors must be articulated and the IMC systems must operate from a less stable base than the gas bearing provides.

e. Mass Properties - Summary weight statements are shown in Tables IV-24, IV-25, and IV-26 for the on-orbit access schemes. Weights of the telescopes were taken from Tables IV-22 and IV-23. A summary weight statement for the baseline no-access concept is shown in Table IV-27. Figure IV-43 locates the cg of the various payloads on a plot of the Shuttle orbiter cg constraints. These weights and cg locations include only the items required when flying a single telescope. The figure indicates that all of these payload cg's are very far forward, and that several exceed the limits of the Shuttle orbiter cg constraint envelope.

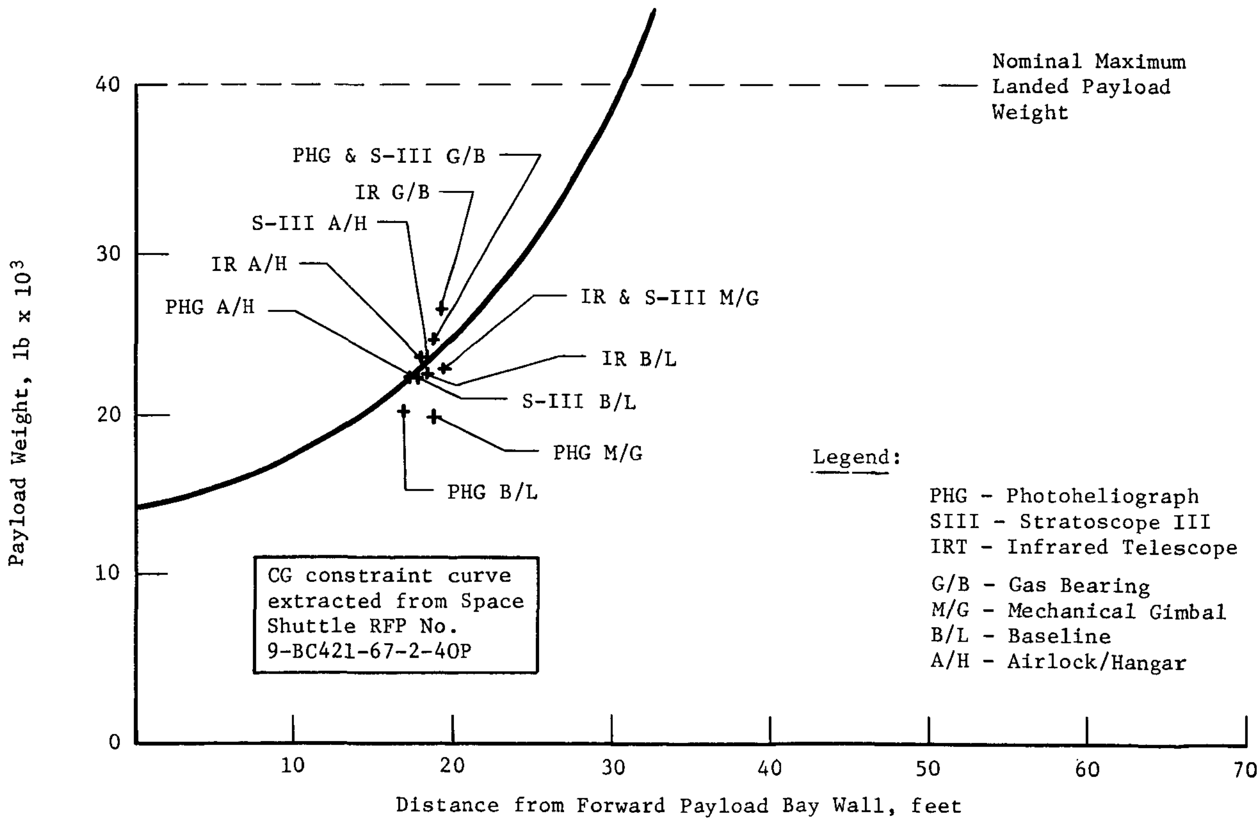

Figure IV-43 Concept CGs vs Shuttle Orbiter CG Constraints

Table IV-24 Hangar Concept Weight Summary

	IR TELESCOPE		PHOTOHELIOGRAPH		STRATOSCOPE III	
	Mass, kg	Weight, lb	Mass, kg	Weight, lb	Mass, kg	Weight, lb
Modified Sortie Lab and Contents	(6561.2)	(14465)	(6327.5	(13950)	(6327.6)	(13950)
Basic Lab (16 ft)	5755.1	12688	5755.1	12688	5755.1	12688
Bulkhead and Support Module	106.6	235	106.6	235	106.6	235
Expandable Airlock	336.1	741	336.1	741	336.1	741
Airlock Pressurizing System	83.5	184	129.7	286	129.7	286
Fuel Cell System	279.9	617				
Support Items External To Lab	(2467.0)	(5439)	(2467.0)	(5439)	(2467.0)	(5439)
Nondeployable Pallet	362.9	800	362.9	800	362.9	800
Stabilizing System (4 CMGs)	946.2	2086	946.2	2086	946.2	2086
Electrical and Data System	22.7	50	22.7	50	22.7	50
Gimbal Mount	1007.4	2221	1007.4	2221	1007.4	2221
Point and Control Reference System	68.9	152	68.9	152	68.9	152
Thermal Insulation	58.9	130	58.9	130	58.9	130
Telescope Installation	(1676.5)	(3696)	(1305.9)	(2879)	(2084.7)	(4596)
Telescope Unit Modified	1612.5	3555	1305.9	2879	2084.7	4596
Instruments (Main)		In Above		In Above		In Above
Instruments (Auxiliary)	64.0	141				
Alternative Items	(129.7)	(286)				
Instrument	42.2	93				
Standby Cryostat	71.2	157				
Support and Alternative Ballast	16.3	36				
TOTAL	10834.4	23886	10100.4	22268	10879.3	23985

Table IV-25 Gas Bearing Concept Weight Summary

	IR TELESCOPE		PHOTOHELIOGRAPH		STRATOSCOPE III	
	Mass, kg	Weight, lb	Mass, kg	Weight, lb	Mass, kg	Weight, lb
<u>Modified Sortie Lab and Contents</u>	(7866.6)	(17343)	(7830.3)	(17263)	(7808.5)	(17215)
Basic Lab (26 ft)	6403.8	14118	6403.8	14118	6403.8	14118
Bulkhead and Support Module	122.5	270	122.5	270	122.5	270
Gas Bearing System	655.4	1445	655.4	1445	655.4	1445
Instrument Mount Plate	264.4	583	264.4	583	264.4	583
Telescope Mount Ring	31.8	70	77.1	170	55.3	122
Fuel Cell System	388.7	857	307.1	677	307.1	677
<u>Support Items External To Lab</u>	(1214.7)	(2678)	(1214.7)	(2678)	(1214.7)	(2678)
CMG Pallet	122.5	270	122.5	270	122.5	270
Stabilizing System (4 CMGs)	946.2	2086	946.2	2086	946.2	2086
Electrical and Data System	18.1	40	18.1	40	18.1	40
Point and Control Reference System	68.9	152	68.9	152	68.9	152
Thermal Insulation	58.9	130	58.9	130	58.9	130
<u>Telescope Installation</u>	(2972.0)	(6552)	(1227.9)	(2707)	(1959.1)	(4319)
Telescope Unit Modified	1423.4	3138	669.1	1475	949.8	2094
Instruments (Main)	61.7	136	217.7	480	762.9	1682
Instruments (Auxiliary)	64.0	141				
Instrument Support	71.2	157*	90.7	200		In Above
Truss or Housing	49.4	109	190.5	420	190.5	420
Ballast	1302.3	2871	59.9	132	55.	123
<u>Alternative Items</u>	(127.4)	(281)				
Instrument	42.2	93				
Standby Cryostat	71.1	157				
Support and Alternative Ballast	14.1	31				
TOTAL	12180.7	26854	10272.9	22648	10982.3	24212

*Cryostat

Table IV-26 Mechanical Gimbal Concept Weight Summary

	IR TELESCOPE		PHOTOHELIOGRAPH		STRATOSCOPE III	
	Mass, kg	Weight, lb	Mass, kg	Weight, lb	Mass, kg	Weight, lb
<u>Modified Sortie Lab and Contents</u>	(7342.7)	(16188)	(7062.8)	(15571)	(7062.8)	(15571)
Basic Lab (26 ft)	6403.7	14118	6403.7	14118	6403.7	14118
Bulkhead and Support Module	110.7	244	110.7	244	110.7	244
Gimbal Support System	429.6	947	429.6	947	429.6	947
Instrument Mount Plate	118.8	262	118.8	262	118.8	262
Fuel Cell System	279.9	617				
<u>Support Items External To Lab</u>	(1214.7)	(2678)	(1214.7)	(2678)	(1214.7)	(2678)
CMG Pallet	122.5	270	122.5	270	122.5	270
Stabilization System (4 CMGs)	946.2	2086	946.2	2086	946.2	2086
Electrical and Data System	18.1	40	18.1	40	18.1	40
Pointing and Control Reference System	68.9	152	68.9	152	68.9	152
Thermal Insulation	59.0	130	59.0	130	59.0	130
<u>Telescope Installation</u>	(1620.2)	(3572)	(1190.7)	(2625)	(1903.3)	(4196)
Telescope Unit	1423.4	3138	669.1	1475	949.8	2094
Instruments (Main)	61.7	136	217.7	480	765.0	1682
Instruments (Auxiliary)	63.9	141				
Instrument Support	71.2	157*	90.7	200	In Above	In Above
Telescope Adapter			22.7	50		
Housing			190.5	420	190.5	420
<u>Alternative Items</u>	(122.5)	(270)				
Instrument	42.2	93				
Stand By Cryostat	71.2	157				
Support	9.1	20				
TOTAL	10300.1	22708	9468.2	20874	10180.8	22445

*Cryostat

Table IV-27 Baseline (no access) Weight Summary

	IR TELESCOPE		PHOTOHELIOGRAPH		STRATOSCOPE III	
	Mass,kg	Weight, lb	Mass, kg	Weight, lb	Mass, kg	Weight, lb
Sortie Lab (16 ft)	5755.1	12688	5755.1	12688	5755.1	12688
Support Items External To Lab	(2467.0)	(5439)	(2467.0)	(5439)	(2467.0)	(5439)
Pallet	362.9	800	362.9	800	362.9	800
Stabilization System (4 CMGs)	946.2	2086	946.2	2086	946.2	2086
Forward Common Mount	481.7	1062	481.7	1062	481.7	1062
Ordnance Package	9.1	20	9.1	20	9.1	20
Forward Gimbal Instruments	516.6	1139	516.6	1139	516.6	1139
Pointing and Control Reference System	68.9	152	68.9	152	68.9	152
Electrical and Data System	22.7	50	22.7	50	22.7	50
Thermal Insulation	58.9	130	58.9	130	58.9	130
Telescope Installation	(2052.1)	(4524)	(997.9)	(2200)	(1792.1)	(3951)
Telescope (Ref 1)	1988.1	4383	997.9	2200	1792.1	3951
Auxiliary Instruments	64.0	141				
TOTAL	10274.2	22651	9220.1	20327	10014.2	22078

6. Operations Analyses

The gas bearing, mechanical gimbal, and hangar/airlock accommodations modes provide the capability for on-orbit servicing operations requiring crew involvement and reducing time available for scientific observation. To assess the effect of these operations, timelines of the functions were prepared and net reductions in data acquisition durations were estimated. As shown in Table IV-28, time requirements per access are not excessive for either mode, and are therefore feasible for sortie missions.

Table IV-28 Access Operations

TELESCOPE	GAS BEARING OR MECHANICAL GIMBAL		HANGAR/AIRLOCK	
	Access Duration, hr: min	Reduction in Observation Time, %	Access Duration, hr: min	Reduction in Observation Time, %
Photoheliograph	2:30	1.6	5:40	2.5
Stratoscope III	2:00	1.0	5:40	2.7
IR Telescope	2:52	1.8	10:00	4.6

In addition to the times shown in the table, the pointing constraints of the concepts were considered. The gas bearing concept imposes a limit on gimbaling freedom of ± 0.0436 radian (± 2.5 deg) about all axes. The mechanical gimbal provides ± 0.262 radian (± 15 deg) about the Y-axis and ± 0.833 radian (± 50 deg) about the X-axis. The baseline mission (does not provide on-orbit access to the telescopes) uses the common mount, which provides hemispherical gimbaling freedom, and results in the operations durations and mission effectiveness shown in Table IV-29.

The hangar/airlock concept also uses the common mount for the telescope. Thus, for this mode, only the use of the access capability reduces time in the mission available for data acquisition. Each access reduces mission effectiveness (from the baseline in Table IV-29) by the values shown in Table IV-28 for each telescope. This is also true for the mechanical gimbal concept, although it should be noted that target selection may be constrained by the gimbaling limits (this is not a severe constraint).

Table IV-29 Operations Effectiveness

TELESCOPE	BASELINE MISSION		GAS BEARING	
	Operations Time, hr: min	Percent of Mission	Operations Time, hr: min*	Percent of Mission
Photoheliograph	123:36	74	122:38	73.4
Stratoscope III	143:00	86	131:26	79
IR Telescope	128:23	77	54:28	32.6

*Operations time for the gas bearing concept were based on one access to the telescope during the mission, which requires the durations shown in Table IV-14.

For the gas bearing mode, the gimbaling freedom of only 0.043 radian (± 2.5 deg) requires orienting the orbiter toward a second target unless one object may be viewed throughout an orbit. Viewing constraints and orbit inclination permit continuous viewing for the photoheliograph and stratoscope III, but not the IR telescope. Resulting times available for data collecting observations, and percentages of total mission times, are shown in Table IV-29. (Note the severe reduction for the IR telescope).

From these timelines and operations analyses, it may be observed that the mechanical gimbal and hangar accommodations modes are satisfactory for all telescopes, and that the gas bearing may be used for the photoheliograph and stratoscope III. Using the gas bearing with the IR telescope reduces mission effectiveness to only 32.6%.

7. Cost Analyses

Estimates were made of the costs of accommodating the photoheliograph and stratoscope III using the baseline, hangar/airlock, gas bearing, and mechanical gimbal concepts. Table IV-30 is a summary of the DDT&E and production costs for each of the concepts investigated.

Table IV-30 Cost Estimates (10^6 dollars)

Cost Elements	BASELINE		HANGAR/AIRLOCK		GAS BEARING		MECHANICAL GIMBAL	
	DDT&E	Prod	DDT&E	Prod	DDT&E	Prod	DDT&E	Prod
Common Mount	17.109	2.603	17.109	2.603	N/A	N/A	8.260	1.223
Az & El Mount	(8.260)	(1.223)	(8.260)	(1.223)	N/A	N/A	(8.260)	(1.223)
3-Axis Gimbal Assembly	(8.849)	(1.380)	(8.849)	(1.380)	N/A	N/A	N/A	N/A
Reference Assembly	8.910	1.684	8.910	1.684	8.910	1.684	8.910	1.684
Sortie Lab Modifications	N/A	N/A	4.633	0.988	4.633	0.988	4.633	0.988
Expandable Airlock	N/A	N/A	15.408	1.948	N/A	N/A	N/A	N/A
Gas Bearing System	N/A	N/A	N/A	N/A	21.18	3.105	N/A	N/A
Instrument Modifications	N/A	N/A	4.388	1.770	1.000	0.100	2.167	0.326
Tertiary Mirror	N/A	N/A	N/A	N/A	(1.000)	(0.100)	(1.000)	(0.100)
Image Motion Comp Delta	N/A	N/A	N/A	N/A	N/A	N/A	(1.167)	(0.226)
Pressure Shell	N/A	N/A	(4.388)	(1.770)	N/A	N/A	N/A	N/A
TOTAL	26.019	4.287	50.448	8.993	35.723	5.877	23.970	4.221

The DDT&E costs were based on: design, development, test, and evaluation of the flight hardware; design, development, and production of GSE; systems support and integration; program management; and a profit of 10%. Cost estimating relationships (CERs) were used to derive the flight hardware design, development, test, and evaluation costs. This cost then served as the reference cost to which cost ratios were applied to determine the costs for GSE, system support and integration, program management, and profit. The cost ratios used were:

$$\text{DDT\&E}_{\text{HARDWARE}} = \text{CER}$$

$$\text{GSE}_{\text{DESIGN \& DEVELOPMENT}} = (29\%)\left(\text{DDT\&E}_{\text{HARDWARE}}\right)$$

$$\text{GSE}_{\text{PRODUCTION}} = (116\%)\left(1^{\text{st}}\ \text{ARTICLE}_{\text{HARDWARE}}\right)$$

$$\text{SYSTEM SUPPORT} = (11\%)\left(\text{DDT\&E}_{\text{HARDWARE}} + \text{GSE}_{\text{DESIGN \& DEVELOPMENT}} + \text{GSE}_{\text{PRODUCTION}}\right)$$

$$\text{PROGRAM MANAGEMENT} = (7.6\%)\left(\text{SYS SUPPORT} + \text{DDT\&E}_{\text{HARDWARE}} + \text{GSE}_{\text{DESIGN \& DEVELOPMENT}} + \text{GSE}_{\text{PRODUCTION}}\right)$$

$$\text{PROFIT} = 10\%\left(\text{PROG MANAGEMENT} + \text{SYS SUPPORT} + \text{DDT\&E}_{\text{HARDWARE}} + \text{GSE}_{\text{DESIGN \& DEVELOPMENT}} + \text{GSE}_{\text{PRODUCTION}}\right)$$

$$\text{DDT\&E}_{\text{TOTAL}} = \text{PROFIT} + \text{PROG MGMT} + \text{SYS SUPPORT} + \text{DDT\&E}_{\text{HARDWARE}} + \text{GSE}_{\text{DESIGN \& DEVELOPMENT}} + \text{GSE}_{\text{PRODUCTION}}$$

The production costs were based on developing the cost of the first article using CERs, and then using this cost as a reference for determining the cost of spares, system support and integration, program management, and profit using cost ratios. The cost ratios used were:

First article = CER

Initial spares = (5%) (1^{st} article)

System support = (11%) (1^{st} article + initial spares)

Program management = (7.6%) (system support + first article + initial spares)

Production costs = profit + program management + system support + initial spares + first article.

The costs shown for the baseline concept reflect the cost of the common telescope mount and the inertial reference system. The common telescope mount is made up of a wide-angle azimuth and elevation mount that provides hemispherical viewing for the telescopes, and a three-axis gimbal with flexible pivots that provides the fine pointing and stabilization for the stratoscope III and photoheliograph. The reference assembly is made up of a set of four precision star trackers and an inertial measurement unit that provides the inertial reference to the telescope mount.

The hangar/airlock costs include the same common telescope mount and reference assembly required for the baseline concept, and the additional costs associated with providing a pressurized environment for the on-orbit access to the stratoscope III and photoheliograph. The Sortie Lab modification is the cost to develop the new aft bulkhead and support structure necessary for the airlock. The cost of the expandable airlock includes the airlock structure, insulation, meteoroid protection, mechanisms, seals, pressurization system, and monitoring equipment. The instrument modification is the cost to provide a pressure shell that encloses the instrument section of the telescopes. The production costs shown are for the production of two instrument pressure shells, one for the stratoscope III and one for the photoheliograph.

The gas bearing concept costs include the reference assembly and Sortie Lab modifications required for the hangar/airlock concept, plus the cost of the gas bearing system and the additional costs for the tertiary mirror that brings the light into the Sortie Lab. The gas bearing costs include the gas bearing, actuators, support structure, airlock, gas system, and gas scavenging system. The cost of installing the tertiary mirror on both the stratoscope III and the photoheliograph are included under instrument modifications.

The mechanical gimbal concept is a variation of the baseline concept, where a limited wide-angle gimbal provides 2 degrees of coarse pointing for the telescopes. Fine pointing and stabilization for the telescopes is provided by IMC systems that are internal to the telescopes. The reference assembly and Sortie Lab modifications required for the hangar/airlock are also required for the mechanical gimbal concept. The costs shown reflect a tertiary mirror and an IMC system for the stratoscope III and the photoheliograph.

In comparing the costs of the four alternatives, it is important to note that the costs shown only reflect the cost of the pointing and stabilization systems necessary for the telescopes, and the costs associated with providing the on-orbit access. The costs of the telescopes themselves and the additional ancillary hardware necessary to outfit a payload are not included.

It is also important to note that the baseline costs will always be required, since the IR telescope and the additional solar instruments will still require this equipment. The cost of providing the on-orbit access for the photoheliograph and stratoscope III will be a delta cost to this baseline.

8. Recommended Approach

The recommended concept, selected at a coordination meeting held at MSFC in February 1973, is the mechanical gimbal concept.

A comparison was made between the three on-orbit access concepts in order to select the recommended concept for the Astronomy Sortie Missions. The major characteristics that were considered, and the evaluation of each concept, are presented in Table IV-31. The baseline concept, which does not provide on-orbit access, is included for comparative purposes.

The airlock/hangar concept was eliminated first, for several reasons. The most important of these was that only periodic access can be provided to the instruments, while the other two concepts provide continuous access for monitoring and adjustments. In addition, costs associated with this concept are considerably higher than for the competing concepts. Favorable characteristics include the capability of using the short Sortie Lab, and the use of the hemispherical viewing mount; however, these features are outweighed by the negative factors mentioned above.

The comparison between the gas bearing and mechanical gimbal concepts shows significant differences in weights and costs, with the mechanical gimbal being superior in both respects. The larger gimbaling capability of the mechanical gimbal allows faster slewing rates than the Shuttle can provide, thus affording greater flexibility of on-orbit operations. The impact on the telescope is greater for the mechanical gimbal concept since the fold mirrors must be articulated, and the IMC system must operate over a larger range.

The mechanical gimbal concept was selected over the gas bearing because of its lower costs and weights, and its greater operational flexibility.

Table IV-31 Concept Comparison

Characteristic	CONCEPTS			
	Gas Bearing	Airlock/Hangar	Mechanical Gimbal	Baseline
Access to Instruments	Continuous	Periodic	Continuous	None
Weight, kg(lb)				
Photoheliograph	10272.9 (22648)	10100.4 (22268)	9468.2 (20874)	9220.1 (20327)
Spectroscope III	10982.3 (24212)	10879.3 (23985)	10180.8 (22445)	10014.2 (22078)
Costs ($\$10^6$)				
DDT&E	35.723	50.448	23.970	26.019
Production	5.877	8.993	4.221	4.287
Impact on Sortie Lab	Long Sortie Lab	Short Sortie Lab	Long Sortie Lab	Short Sortie Lab
Impact on Telescope	Moderate	Moderate	Greatest	--
Operational Efficiency,%				
PHG	73.4	71.5	73.4	74
SIII	79.0	83.3	79.0	86

D. PLANNING DATA

1. Project Planning Requirements

The gross planning requirments for the Astronomy Sortie Missions Definition Study (Ref 1) are generally unchanged as a result of the follow-on study, except for specific numbers of flights of the payloads and the project duration of 12 years. In the study continuation, a flight sequence and the project duration were not defined, but program development requirements were generated for individual telescopes, arrays, and instruments. The objective was to provide planning data that could be used to synthesize workable programs having a range of durations, numbers of flights, and costs.

Although the number of flights and program duration were not specified, several flights of each instrument over a period of years are required to satisfy scientific objectives. Therefore, the gross planning requirements presented previously for engineering and manufacturing, testing, quality and reliability assurance, facilities, and project management are applicable to any program derived from the elements analyzed in this study.

2. Schedules

Schedules were developed for each flight hardware item that was considered for inclusion in an Astronomy Sortie Mission project. Since no program was defined, a program milestone schedule and network could not be developed. However, it is expected that when the program is defined, consideration of long-lead-time (LLT) developments and early authorization-to-proceed will be required for some elements.

a. Operations - The operational concept involving the Payload Integration Center (PIC) at MSFC, a Launch and Landing Site, and a Space Astronomy Control Facility (SACF) remains the baseline. Initial integration and test for the first flight is expected to require 6 months. The totally integrated Sortie Lab and pallet, with subsystems and experiments, is then loaded in the Super Guppy and delivered to the launch site for 3 months of prelaunch operation before the first flight.

For the small UV instruments to be flown on flights when the opportunity is presented, integration into the Sortie Lab and pallet may not be required. Prelaunch operations for these instruments will be compatible with the primary payload.

The payloads are returned after each flight. The Sortie Lab and pallet with experiments are then shipped to the PIC at MSFC, the experiments are removed, and the Sortie Lab and pallet are refurbished to receive other experiments. After integration of other telescopes and arrays, the integrated payload is tested, accepted as flight-ready, and shipped to the launch site for another sortie flight.

Flight payloads do not pass through the SACF. Film exposed in missions will be returned to the SACF for processing, and scientists there must have communications with the flight (through mission control), but the payload handling capabilities necessary at the PIC-MSFC and at the launch site are not needed at SACF. The overall turnaround time for a payload to complete one flight and be refurbished for another flight is 10 weeks (Fig. IV-44).

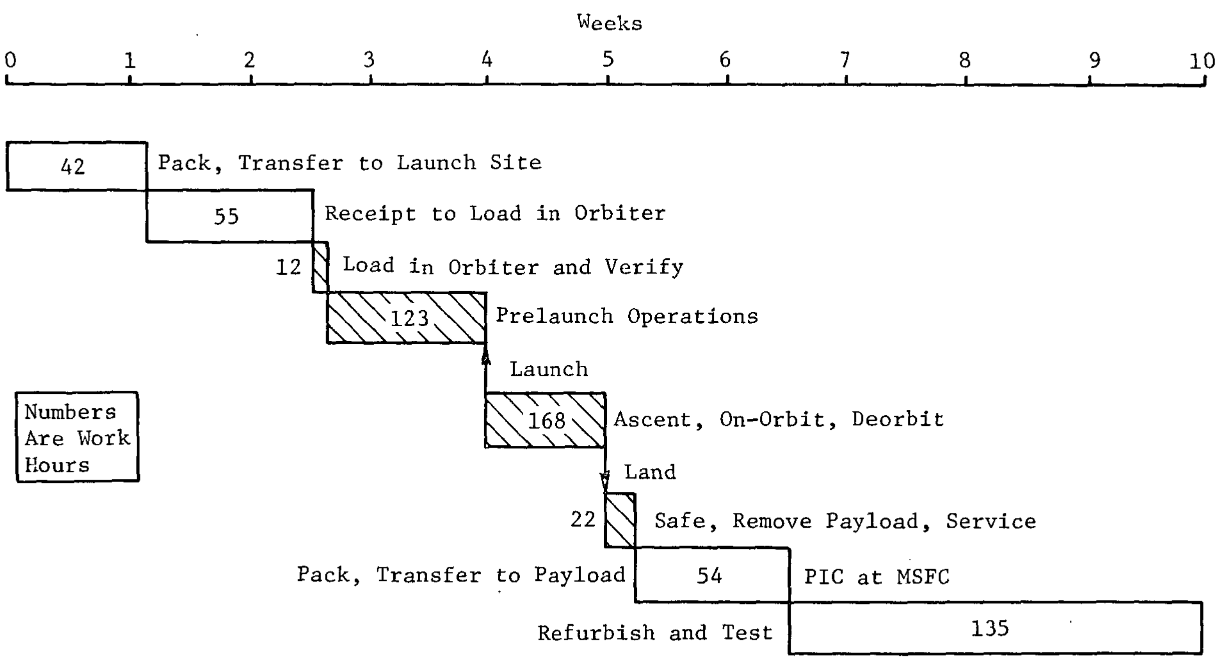

Figure IV-44 Turnaround Schedule

b. Facilities and GSE - The primary facilities to be activated are the PIC-MSFC, the launch and landing site, and the SACF. These facilities will be outfitted with GSE developed concurrently with the flight hardware by the hardware manufacturer, and payload handling and support equipment GSE developed by the program contractor.

Lead times for activation of facilities, GSE development, and telescopes and arrays support equipment are:

Item	Lead Time, Months before First Flight
Facilities	
PIC at MSFC	9
Launch and Landing Site	3
SACF	3
GSE Development	
Payload Support Equipment	9
Delivery to MSFC	6
Delivery to Launch Site	6
Delivery to SACF	6
Telescopes and Arrays Support Equipment	3 to 6

c. Telescopes, Arrays, and UV Instruments - Experiment hardware will be built using a single article approach, in which the flight unit will be subjected to any development tests, and then be modified and serviced for flight acceptance. It is expected that each telescope and array will be individually contracted for by NASA and provided to this project.

Development and production of experiment hardware should be scheduled so that delivery will lead expected first flight by 9 months (Fig. IV-45).

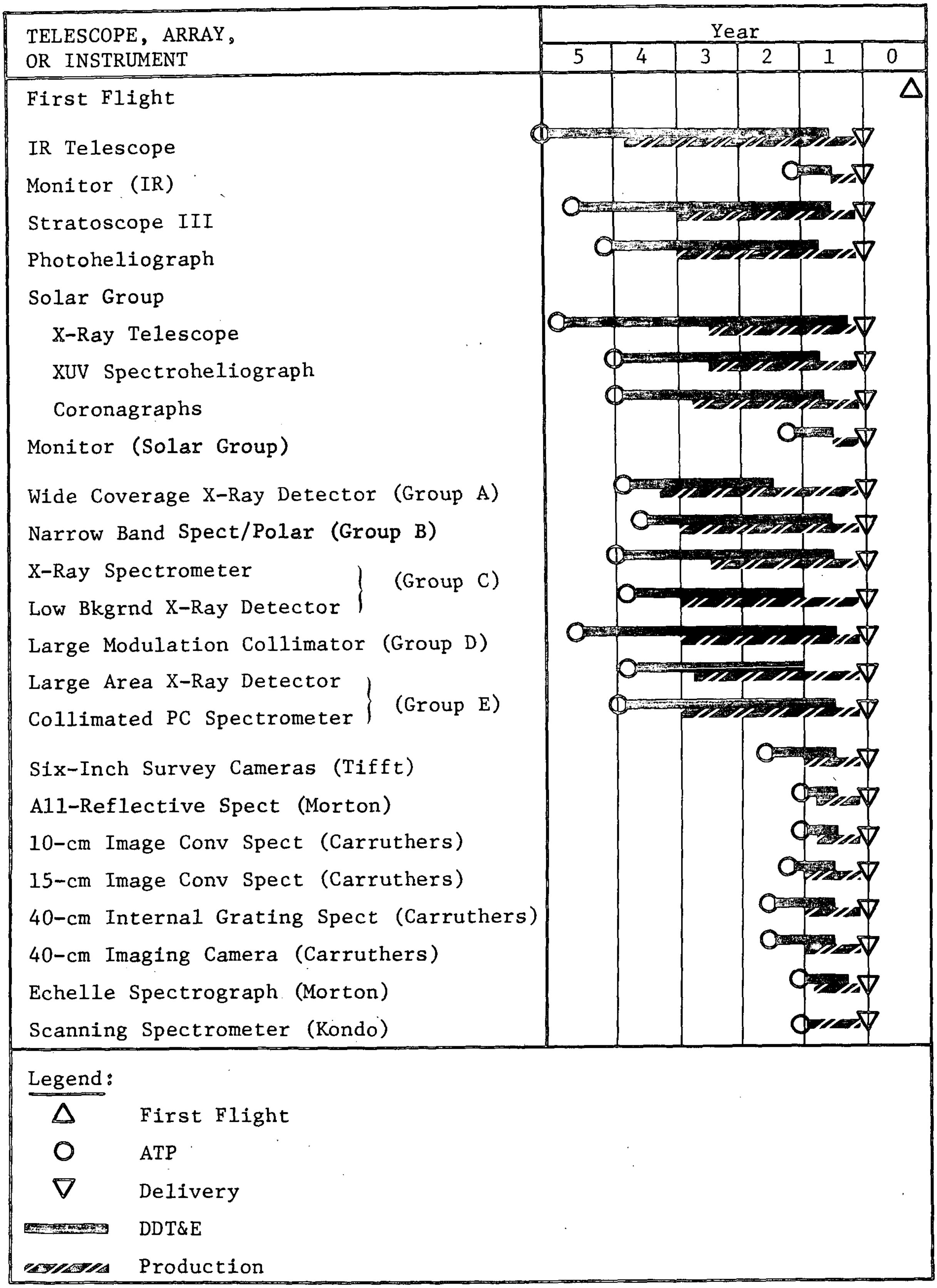

Figure IV-45 Schedule for Telescopes, Arrays and Instruments *d. Subsystems for Intermediate Telescopes and Arrays* - Test and flight articles are required for the pointing and control, structures, electronic, and thermal control subsystems of the Sortie Lab and pallet.

The test article will be used by the project contractor to conduct systems tests (structural loading, dynamic, natural environments, and limited function) at the contractor's plant. The flight unit will undergo preintegration acceptance tests before shipment to the PIC-MSFC, where integration with the Sortie Lab and pallet is performed. The pointing and control system is the long-lead time development item (Fig. IV-46) requiring 3¼ years for DDT&E and initial production. All subsystems must be delivered 1 year before first flight launch date.

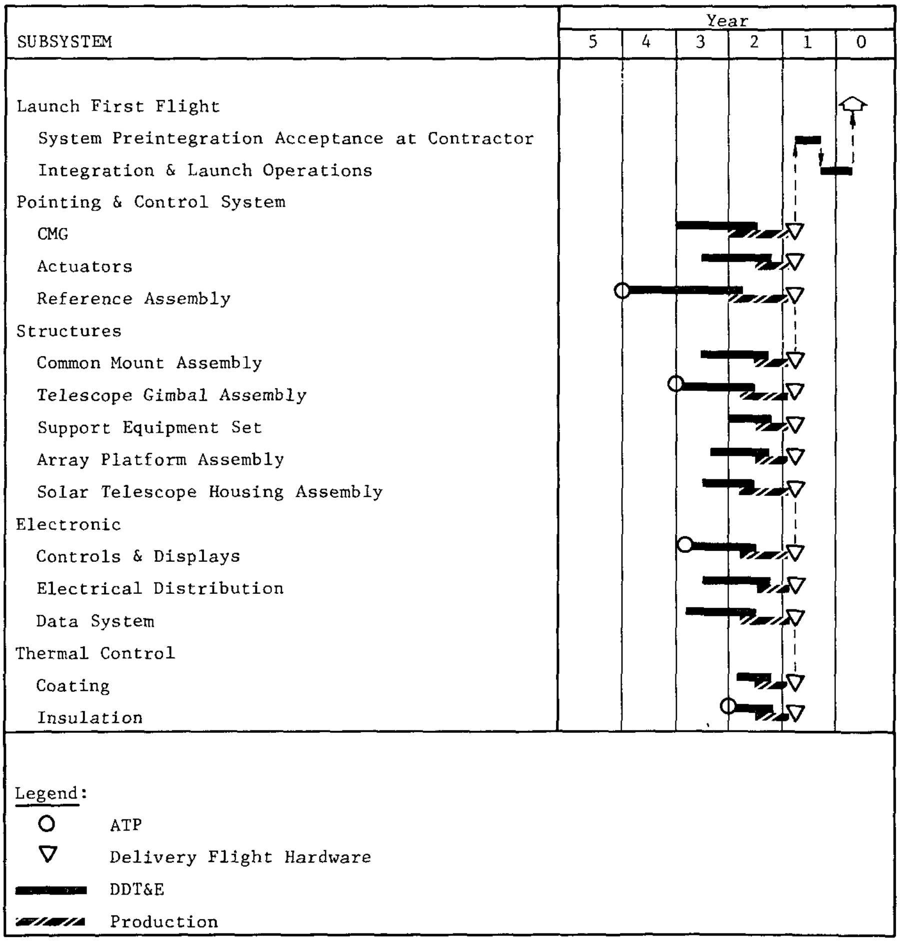

Figure IV-46 Schedule for Subsystems Used with Intermediate Telescopes and Arrays *e. Subsystems for Small UV Instruments* - Test and flight articles are required for the pointing and control, structures, and electronic subsystems of the small UV instruments on flights of opportunity. Integration of the flight hardware into the carrier may be at the launch site or at a prime payload integrating contractor's facility. Schedules are shown in Figure IV-47; the period provided for integration of the subsystems is 6 months for the first flight.

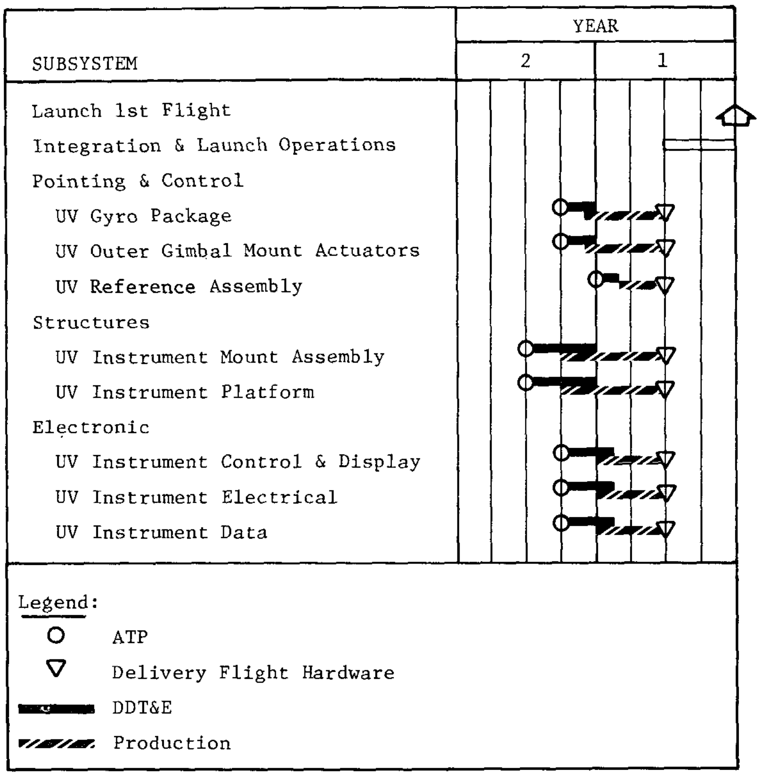

Figure IV-47 Schedule for Subsystems Used with Small UV Instruments

3. Supporting Research and Technology

No supporting research and technology (SRT), in addition to that identified in Reference 1, was identified in this continuing study. It should be noted that the schedules shown in the final report for SRT items were based on the flight schedule requirements of the project as then defined. Changes in the project schedules (to be generated with consideration for the results of this follow-on study) will effect the SRT schedule dates. The span times shown for these items in the final report have not been revised.

V. COST ESTIMATES

A. COSTING APPROACH, METHODOLOGY, AND RATIONALE

The estimates provided in this section describe the cost of development, first unit production, and operational support for various items of hardware and operations that are candidates for an Astronomy Sortie Mission Project. The estimates do not describe the total cost of a particular program of numerous flights, since no specific program has been defined. Costs are presented in a manner that permits combining elements in desired variations to synthesize astronomy programs for Shuttle sortie missions.

Parametric costing was used to develop the prices for hardware and operations using cost estimating relationships (CERs), cost ratios, and factors in conjunction with detailed estimates. The CERs, cost ratios, and factors used were developed from Martin Marietta's experience on programs such as Skylab and Viking, and from data bank information of other industry programs. Generally, subsystem hardware was priced using CERs; the telescopes, arrays, and instruments were priced using detailed estimates and CERs. Software elements, such as project management and systems support, were estimated using cost ratios and factors. Operations elements were priced using detailed estimates and CERs. Estimates were derived for design, development, test and evaluation (DDT&E), first unit production, and operations.

A Work Breakdown Structure (WBS) dictionary, listing in numerical order the elements considered for this project [as defined by the data requirements (DR)], is presented in Section E. The elements of the WBS were followed to present costs for non-recurring (DDT&E), recurring (production), and recurring (operations) (Section B). Floating items costs are included in these prices at the level at which they occur. The costs are not accumulated to a project level, since no project is defined and, therefore, there is no basis for combination.

The general ground rules and assumptions used in this pricing are:

1) Fiscal 1973 constant dollars;

2) Sortie Lab and pallet are GFE -- costs are not included herein;

3) Shuttle operations cost is excluded. The proton flux detector was considered part of Shuttle operations cost;

4) NASA center cost is excluded -- costs are not included herein;

5) Experiment and subsystem configurations remain fixed;

6) No contingencies or discounts are included;

7) Costs include 10% profit;

8) Facility costs are excluded, as they are program dependent, and estimates provided do not describe a program;

9) A prime contractor will be responsible for developing the subsystems, producing them, and supporting their integration into the Sortie Lab and pallet at the PIC at MSFC;

10) The telescopes, arrays, and instruments will be developed by various industry or university associate contractors and will be purchased directly by NASA.

B. COST ESTIMATES BY WBS ELEMENT

Estimates were prepared for non-recurring (DDT&E) on Cost Data Form - A(1), for recurring (production) on Cost Data Form - A(2), and for recurring (operations) on Cost Data Form - A(3). (The forms are included in this section.)

1. <u>Cost Data Form - A(1) Non-Recurring (DDT&E)</u>

A description of the contents of each column of Form - A(1) follows:

1) Identification Number - The 13-digit WBS number of the item of cost;

2) WBS Identification - The alphanumeric nomenclature of the item from the WBS;

3) WBS Level - The level at which the element is carried;

4) Expected Cost - The cost estimate for the WBS item;

5) Confidence Rating - A value of 1 through 4 representing the estimator's confidence in the estimate shown in the WBS item cost column. The values were obtained by reviewing the criteria presented in the *Phase A and Phase B Studies Cost Estimates Document*, DRD No. MF-030A, Table 1, "Confidence Level Groups for Cost Estimates", and selecting the value most applicable;

6) T_d - The duration of the costs of the DDT&E activity in months;

7) T_s - The lead time (months) measured from the start of cost accrual for the item to the launch milestone;

8) Spread Function - An index number representing a cost distribution curve that the estimator recommends for the time phasing of costs over T_d. Standard distributions from Figure 8 of the *Phase A and Phase B Studies Cost Estimates Document*, No. MF-030A, were used where applicable.

a. DDT&E for Telescopes, Arrays, and Instruments - Development of each telescope, array, and instrument requires producing one unit, using the unit for tests and checkouts, and updating the same unit for flight. Costs for these items are provided herein for information purposes, and do not include prime contractor G & A or profit in addition to that of the associate contractors, since they will be procured directly by NASA.

"Expected Cost" (column 4) of Form - A(1) for telescopes, arrays, and instruments is defined as follows:

EXPECTED COST = BASIC DDT&E + SYSTEMS SUPPORT.

Where:

BASIC DDT&E includes engineering analyses, design specification preparation, tooling design and fabrication, test criteria, development tests, but *no* test article; and SYSTEMS SUPPORT = 11% OF BASIC DDT&E.

b. DDT&E for Subsystems - The subsystems consist of assemblies and components that are either qualified and are available off the shelf, or require extensive development. The inherent project advantages of returning each payload from orbit, and the relatively short on-orbit stay times for each flight, were considered in recommending limited development tests requiring only one test article for the subsystems. Conformance with orbiter certification level requirements for qualification is planned for all "critical" components.

"Expected Cost" (column 4) of Form - A(1) for the subsystems assemblies and components is defined as follows:

EXPECTED COST = A + B + C + D.

Where:

A = BASIC DDT&E + DEVELOPMENT UNIT + GSE DEVELOPMENT, and BASIC DDT&E includes engineering analysis, design, specification preparation, tooling design and fabrication, test criteria, and development tests;

DEVELOPMENT UNIT is cost of unit used for testing;

GSE DEVELOPMENT is 29% of BASIC DDT&E;

B = GSE PRODUCTION, which was estimated as 116% (first flight unit + initial spares);

C = SYSTEMS SUPPORT, which was estimated as 11% (A + B);

D = PROJECT MANAGEMENT, which was estimated as 7.6% (A + B + C).

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
CONTRACT NO. NAS8-28144

COST DATA FORM – A(1)
NON-RECURRING (DDT&E)

DATE MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-00-00-00	PAYLOADS	4					
01-001-05-01-00-00	TELESCOPES	5	52.218				
01-001-05-01-01-00	IR TELESCOPE	6	11.655	2	54	69	
01-001-05-01-02-00	STRATOSCOPE III	6	9.324	2	48	63	
01-001-05-01-03-00	PHOTOHELIOGRAPH	6	5.728	2	39	57	
01-001-05-01-04-00	X-RAY TELESCOPE	6	19.592	2	54	66	
01-001-05-01-05-00	XUV SPECTROHELIOGRAPH	6	2.387	2	39	57	
01-001-05-01-06-00	CORONAGRAPHS	6	3.309	2	39	57	
01-001-05-01-07-00	MONITORS	6	0.223	2	9	24	
01-001-05-02-00-00	ARRAYS	5	43.680				
01-001-05-02-01-00	LARGE AREA X-RAY DET	6	5.495	2	33	54	
01-001-05-02-02-00	WIDE COVERAGE X-RAY	6	2.498	2	27	54	
	DETECTOR						
01-001-05-02-03-00	LARGE MODULATION	6	7.715	2	48	63	
	COLLIMATOR						
01-001-05-02-04-00	NARROW BAND SPECTROM/	6	6.993	2	36	51	
	POLARIMETER						
01-001-05-02-05-00	COLLIMATED PC SPECTRO-	6	5.661	2	42	57	
	METER						

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COST DATA FORM – A(1)
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DATE MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-02-06-00	GAMMA-RAY SPECTROMETER	6	8.103	2	42	57	
01-001-05-02-07-00	LOW BACKGROUND γ -RAY	6	7.215	2	33	54	
	DETECTOR						
01-001-05-02-08-00	PROTON FLUX DETECTOR	6	N/A				
01-001-05-03-00-00	POINTING & CONTROL SYS	5	37.624		30	48	50/60
01-001-05-03-01-00	CMG ASSEMBLY	6	3.933				
01-001-05-03-01-01	DOUBLE GIMBAL CMGS	7	3.195	4			
01-001-05-03-01-02	INVERTERS	7	0.408	4			
01-001-05-03-01-03	IMU	7	0.330	4			
01-001-05-03-02-00	COMMON MOUNT ACTUATORS	6	2.272				
01-001-05-03-02-01	AZ POINTING	7	1.140	3			
01-001-05-03-02-02	DEPLOYMENT	7	1.132	3			
01-001-05-03-03-00	TELESCOPE GIMBAL	6	3.777				
	ACTUATORS						
01-001-05-03-03-01	EL POINTING &	7	1.565	1			
	STABILITY						
01-001-05-03-03-02	AZ STABILITY	7	0.901	1			
01-001-05-03-03-03	ROLL	7	0.640	3			
01-001-05-03-03-04	PITCH & YAW	7	0.671	3			

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COST DATA FORM – A(1)
NON-RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-03-04-00	ARRAY PLATFORM	6	1.004				
	ACTUATOR						
01-001-05-03-04-01	EL POINTING	7	1.004	3			
01-001-05-03-05-00	REFERENCE ASSY	6	23.568				
01-001-05-03-05-01	STRAPDOWN STAR	7	4.497	1			
	TRACKERS						
01-001-05-03-05-02	TELESCOPE IMU	7	4.413	3			
01-001-05-03-05-03	FINE SUN SENSOR	7	2.205	4			
01-001-05-03-05-04	BORESIGHTED STAR	7	3.523	3			
	TRACKER						
01-001-05-03-05-05	CORRELATION TRACKER	7	9.110	3			
01-001-05-03-06-00	UV GYRO PACKAGE	6	0.111	3			
01-001-05-03-07-00	UV OUTER GIMBAL	6	1.824				
	MOUNT ACTUATORS						
01-001-05-03-07-01	EL POINTING &	7	1.116	3			
	STABILITY						
01-001-05-03-07-02	AZ STABILITY	7	0.708	3			

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-03-08-00	UV REFERENCE ASSY	6	1.135		3	12	50/60
01-001-05-03-08-01	VIDICON CAMERA	7	0.503	3			
01-001-05-03-08-02	REFERENCE CAMERA	7	0.266	3			
01-001-05-03-08-03	SUN-EARTH SENSOR	7	0.183	3			
01-001-05-03-08-04	RADIATION DETECTOR	7	0.183	3			

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-04-00-00	STRUCTURES	5	31.822		18	36	50/60
01-001-05-04-01-00	COMMON MOUNT ASSY	6	5.988				
01-001-05-04-01-01	AZ TABLE	7	1.485	3			
01-001-05-04-01-02	AZ YOKE	7	2.329	3			
01-001-05-04-01-03	DEPLOYMENT YOKE	7	1.027	3			
01-001-05-04-01-04	DEPLOYMENT GEAR-	7	0.870	3			
	MOTORS & LAUNCH						
	LOCKS						
01-001-05-04-01-05	JETTISON EQUIPMENT	7	0.277	3			
01-001-05-04-02-00	TELESCOPE GIMBAL ASSY	6	5.743				
01-001-05-04-02-01	OUTER GIMBAL RING	7	1.361	3			
01-001-05-04-02-02	OUTER ROLL RING	7	1.821	3			
01-001-05-04-02-03	INNER ROLL RING	7	1.151	3			
01-001-05-04-02-04	ROLL GEAR	7	0.087	3			
01-001-05-04-02-05	TELESCOPE P&C	7	0.396	3			
	PLATFORM						
01-001-05-04-02-06	GIMBAL GEARMOTORS &	7	0.927	3			
	LAUNCH LOCKS						

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-04-03-00	ARRAY PLATFORM ASSY	6	3.187				
01-001-05-04-03-01	ARRAY MOUNT	7	2.719	3			
01-001-05-04-03-02	PLATFORM GEARMOTORS	7	0.468	3			
	& LAUNCH LOCKS						
01-001-05-04-04-00	SUPPORT EQUIPMENT SET	6	3.125				
01-001-05-04-04-01	CMG SUPPORT	7	0.315	3			
	STRUCTURES						
01-001-05-04-04-02	W.C. X-RAY DETECTOR	7	1.183	3			
	MOUNT						
01-001-05-04-04-03	γ-RAY SPECTROM.	7	1.627	3			
	HOUSING & EXTENSION						
	MECHANISM						
01-001-05-04-05-00	SOLAR TELESCOPE	6	6.633				
	HOUSING ASSEMBLY						
01-001-05-04-05-01	TUBULAR STRUCT	7	4.100	3			
01-001-05-04-05-02	BULKHEADS	7	2.039	3			
01-001-05-04-05-03	SUNSHIELD (FIBER)	7	0.412	3			
01-001-05-04-05-04	APERTURE DOORS	7	0.061	3			
01-001-05-04-05-05	DOOR ACTUATORS	7	0.021	3			

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-04-06-00	UV INSTRUMENT MOUNT	6	4.064				
	ASSEMBLY						
01-001-05-04-06-01	AZIMUTH TABLE	7	0.843	3			
01-001-05-04-06-02	AZIMUTH YOKE	7	1.401	3			
01-001-05-04-06-03	LAUNCH LOCKS	7	0.769	3			
01-001-05-04-06-04	JETTISON EQUIPMENT	7	0.549	3			
01-001-05-04-06-05	AZ GEARMOTORS	7	0.306	3			
01-001-05-04-06-06	FITTINGS/FIXTURES	7	0.196	3			
01-001-05-04-07-00	UV INSTRUMENT	6	3.082				
	PLATFORM						
01-001-05-04-07-01	EQUIP. PLATFORM	7	0.060	3			
01-001-05-04-07-02	GIMBAL RING	7	0.800	3			
01-001-05-04-07-03	OUTER ROLL RING	7	1.070	3			
01-001-05-04-07-04	INNER ROLL RING	7	0.712	3			
01-001-05-04-07-05	PLATFORM GEARMOTORS	7	0.168	3			
01-001-05-04-07-06	FITTINGS/FIXTURES	7	0.272	3			

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-05-00-00	ELECTRONICS	5	20.690		18	36	50/60
01-001-05-05-01-00	CONTROL & DISPLAY	6	13.465	3			
01-001-05-05-02-00	ELECTRICAL	6	1.433				
01-001-05-05-02-01	LOAD CENTER SWITCH	7	0.247	3			
01-001-05-05-02-02	FEEDER CABLES	7	0.841	3			
01-001-05-05-02-03	JUNCTION BOX	7	0.345	3			
01-001-05-05-03-00	DATA	6	2.415				
01-001-05-05-03-01	DATA BUS INTERFACE	7	0.135	3			
01-001-05-05-03-02	COAX DATA BUS	7	0.296	3			
01-001-05-05-03-03	PALLET INSTRUMENTA-	7	0.933	3			
	TION BOX						
01-001-05-05-03-04	DATA PROCESSOR	7	1.051	3			
01-001-05-05-04-00	UV INSTRUMENT	6	1.471	3			
	CONTROL & DISPLAY						
01-001-05-05-05-00	UV INSTRUMENT	6	0.591				
	ELECTRICAL						
01-001-05-05-05-01	LOAD CENTER SWITCH	7	0.128	3			
01-001-05-05-05-02	FEEDER CABLES	7	0.258	3			
01-001-05-05-05-03	JUNCTION BOX	7	0.205	3			

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-05-06-00	UV INSTRUMENT DATA	6	1.315				
01-001-05-05-06-01	TELEMETRY	7	0.190	3			
01-001-05-05-06-02	PROGRAMMER	7	0.653	3			
01-001-05-05-06-03	MINI-COMPUTER	7	0.472	2			
01-001-05-06-00-00	THERMAL CONTROL	5	3.615	3	6	24	50/60
01-001-05-06-01-00	THERMAL COATING	6					
01-001-05-06-02-00	MULTILAYER INSULATION	6					
01-001-05-07-00-00	SMALL UV INSTRUMENTS	5	9.412				
01-001-05-07-01-00	6-IN SURVEY CAMERAS	6	1.998	2	12	27	
01-001-05-07-02-00	ALL REFLECTIVE	6	0.777	2	6	21	
	SPECTROGRAPH						
01-001-05-07-03-00	10 CM IMAGE CONVERT	6	0.777	2	6	21	
	SPECTROGRAPH						
01-001-05-07-04-00	15-CM IMAGE CONVERT	6	0.932	2	9	24	
	SPECTROGRAPH						
01-001-05-07-05-00	40-CM INTERNAL GRATING	6	1.998	2	12	27	
	SPECTROGRAPH						
01-001-05-07-06-00	40-CM IMAGING CAMERA	6	1.998	2	12	27	
01-001-05-07-07-00	ECHELLE SPECTROGRAPH	6	0.932	2	9	21	

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COST DATA FORM – A(1)
NON-RECURRING (DDT&E)

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
01-001-05-07-08-00	SCANNING SPECTROMETER	6	N/A				

2. Cost Data Form - A(2) Recurring (Production)

A description of the contents of each column of Form - A(2) follows:

1) Identification Number - The 13-digit WBS number of the item of cost;

2) WBS Identification - The alphanumeric nomenclature of the item from the WBS;

3) WBS Level - The level at which the element is carried;

4) Number of Units - The quantity of units for each WBS item used in the production phase for one flight or mission without allowance for spares;

5) First Unit Cost T_1 - The cost to produce theoretical first item (this is the intercept of the learning curve on a log-log plot);

6) Expected Cost - The cost estimate for the WBS item (refer to specific definitions for telescopes, arrays, and instruments and for subsystems defined in later paragraphs);

7) Reference Unit - The production sequence number of the first unit that is used in the recurring phase of the program;

8) Confidence Rating - A value of 1 through 4 representing the estimator's confidence in the estimate shown in the WBS item cost column. The values were obtained by reviewing the criteria presented in the *Phase A and Phase B Studies Cost Estimated Document*, DRD No. MF-030A, Table 1, "Confidence Level Groups for Cost Estimates," and selecting the value most applicable;

9) T_d - The duration (months) of costs of producing the flight article;

10) T_s - The lead time (months) measured from the start of cost accrual for the item to the launch milestone;

11) Spread Function - An index number representing a cost distribution curve that the estimator recommends for the time phasing of costs over T_d. Standard distributions from Figure 8 of the *Phase A and Phase B Studies Cost Estimates Document*, No. MF-030A, were used where applicable;

12) Learning Index - A numerical index of a learning rate related to the recurring cost.

a. Recurring (Production) for Telescopes, Arrays, and Instruments - Each telescope, array, or instrument unit that was produced for developing the item, will be updated as required for flight. The "Expected Cost" shown in Form - A(2) for telescopes, arrays, and instruments is defined as follows:

EXPECTED COST = BASIC PRODUCTION + INITIAL SPARES + SYSTEMS SUPPORT.

Where:

BASIC PRODUCTION is the first UNIT COST T_1 (column 5) for items requiring one unit (column 4) [for items having more than one unit, BASIC PRODUCTION is derived by applying the Learning Index (column 13) to the number of units and the first Unit Cost T_1];

INITIAL SPARES is derived by applying a percentage, which is variable depending on the item and the expected failure or wearout rate, to the BASIC PRODUCTION cost;

SYSTEMS SUPPORT = 11% of (BASIC PRODUCTION + INITIAL SPARES).

b. Recurring (Production) for Subsystems - Production costs for the flight hardware were estimated by using CERs. Costs were estimated at the component or subassembly level. This was required to enable a consistant application of a 90% improvement curve due to the variable quantity of each item required for DDT&E, production, and operations (spares). The "Expected Cost" shown in Form - A(2) for the subsystems, assemblies, and components is defined as follows:

EXPECTED COST = A + B + C.

Where:

A = BASIC PRODUCTION + INITIAL SPARES and BASIC PRODUCTION is the first UNIT COST T_1 (column 5) for items requiring one unit (column 4). [For items having more than one unit, BASIC PRODUCTION is derived by applying the Learning Index (column 13) to the number of units and the 1st UNIT COST T_1];

INITIAL SPARES is derived by applying a percentage, which is variable depending on the item and the expected failure or wear-out rate, to the BASIC PRODUCTION cost;

B = SYSTEMS SUPPORT, which was estimated as 11% of (A);

and C = PROJECT MANAGEMENT, which was estimated as 7.6% of (A +B).

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
CONTRACT NO. NAS8-28144

COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT	LEARN INDEX
01-001-05-00-00-00	PAYLOADS	4										
01-001-05-01-00-00	TELESCOPES	5			44.185							
01-001-05-01-01-00	IR TELESCOPE	6	1	12.000	13.720	1	13.720	2	45	54		90%
01-001-05-01-02-00	STRATOSCOPE III	6	1	7.200	8.711	1	8.811	2	36	45		90%
01-001-05-01-03-00	PHOTOHELIOGRAPH	6	1	4.610	5.885	1	5.885	2	36	45		90%
01-001-05-01-04-00	X-RAY TELESCOPE	6	1	8.200	9.921	1	9.921	2	30	39		90%
01-001-05-01-05-00	XUV SPECTROHELIOGRAPH	6	1	1.000	1.254	1	1.254	2	30	39		90%
01-001-05-01-06-00	CORONAGRAPHS	6	1	1.950	2.317	1	2.317	2	33	42		90%
01-001-05-01-07-00	MONITORS	6	1	2.020	2.377	1	2.377	2	6	15		90%
01-001-05-02-00-00	ARRAYS	5			58.561							
01-001-05-02-01-00	LARGE AREA X-RAY	6	1	4.580	5.846	1	5.846	2	33	42		90%
01-001-05-02-02-00	WC X-RAY	6	1	7.800	9.004	1	9.004	2	39	48		90%
01-001-05-02-03-00	LARGE MOD. COLL	6	1	5.180	6.555	1	6.555	2	36	45		90%
01-001-05-02-04-00	NARROW BAND SPEC.	6	1	10.200	12.907	1	12.907	2	36	45		90%
01-001-05-02-05-00	COLL P.C. SPECTROM	6	1	7.300	9.318	1	9.318	2	36	45		90%
01-001-05-02-06-00	γ-RAY SPECTROM	6	1	4.500	5.694	1	5.694	2	30	39		90%
01-001-05-02-07-00	LOW BKGD γ-RAY DET	6	1	7.300	9.237	1	9.237	2	36	45		90%
01-001-05-02-08-00	PROTON FLUX DETEC	6	1	N/A	N/A	1	N/A					

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
CONTRACT NO. NAS8-28144

COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73
PAGE 2 OF 7

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT	LEARN INDEX
01-001-05-03-00-00	POINT & CONTROL	5			8.114				15	27	50/60	
01-001-05-03-01-00	CMG ASSY	6			2.432							
01-001-05-03-01-01	DOUBLE GIMBAL CMG'S	7	3	0.630	1.961	2	0.567	4				90%
01-001-05-03-01-02	INVERTERS	7	3	0.060	0.186	2	0.064	4				
01-001-05-03-01-03	IMU	7	1	0.260	0.285	2	0.285	3				
01-001-05-03-02-00	COMMON MOUNT	6		0.325								
01-001-05-03-02-01	AZ POINTING	7	1	0.160	0.179	2	0.179	3				90%
01-001-05-03-02-02	DEPLOYMENT	7	1	0.130	0.146	2	0.146	3				
01-001-05-03-03-00	TELE GIMBAL ACT	6			0.577							
01-001-05-03-03-01	EL POINTING & STAB	7	1	-.220	0.248	2	0.248	1				90%
01-001-05-03-03-02	AZ STABILITY	7	1	0.130	0.147	2	0.147	1				
01-001-05-03-03-03	ROLL	7	1	0.080	0.091	2	0.091	3				
01-001-05-03-03-04	PITCH & YAW	7	1	0.080	0.091	2	0.091	3				
01-001-05-03-04-00	ARRAY PLATFORM ACT	6			0.158							
01-001-05-03-04-01	EL POINTING	7	1	0.140	0.158	2	0.158	3				90%

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
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COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73
PAGE 3 OF 7

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT	LEARN INDEX
01-001-05-03-05-00	REFERENCE ASSY	6			3.655							
01-001-05-03-05-01	STRAPDOWN STAR TRK	7	4	0.340	1.396	2	0.365	1				90%
01-001-05-03-05-02	TELESCOPE IMU	7	1	0.260	0.288	2	0.288	3				90%
01-001-05-03-05-03	FINE SUN SENSOR	7	1	0.740	0.819	2	0.819	4				90%
01-001-05-03-05-04	BS STAR TRACKER	7	1	0.280	0.310	2	0.310	3				90%
01-001-05-03-05-05	CORREL. TRACKER	7	1	0.760	0.842	2	0.842	3				90%
01-001-05-03-06-00	UV GYRO PACKAGE	6	1	0.010	0.012	2	0.012	3				90%
01-001-05-03-07-00	UV OUTER GIM MT. ACT.	6			0.591							
01-001-05-03-07-01	EL. POINT. & STABIL.	7	2	0.160	0.350	2	0.172	2				90%
01-001-05-03-07-02	AZ STABIL.	7	2	0.110	0.241	2	0.118	2				90%
01-001-05-03-08-00	UV REFERENCE ASSY	6			0.364							
01-001-05-03-08-01	VIDICON CAMERA	7	1	0.150	0.166	2	0.166	3				90%
01-001-05-03-08-02	REFERENCE CAMERA	7	1	0.080	0.088	2	0.088	3				90%
01-001-05-03-08-03	SUN-EARTH SENS	7	1	0.050	0.055	2	0.055	3				90%
01-001-05-03-08-04	RADIATION DET	7	1	0.050	0.055	2	0.055	3				90%

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
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COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73
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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT	LEARN INDEX
01-001-05-04-00-00	STRUCTURES	5			4.554				12	24	50/60	
01-001-05-04-01-00	COMMON MOUNT ASSY	6			0.898							
01-001-05-04-01-01	AZ TABLE	7	1	0.170	0.185	2	0.185	3				90%
01-001-05-04-01-02	AZ YOKE	7	1	0.266	0.288	2	0.288	3				90%
01-001-05-04-01-03	DEPLOY YOKE	7	1	0.177	0.127	2	0.127	3				90%
01-001-05-04-01-04	DEP. G.M. & L.L.	7	2	0.125	0.263	2	0.134	3				90%
01-001-05-04-01-05	JETTISON EQUIP.	7	1	0.032	0.035	2	0.035	3				90%
01-001-05-04-02-00	TELESCOPE GIM. ASSY.	6			0.894							
01-001-05-04-02-01	OUTER GIM. RING	7	1	0.154	0.173	2	0.173	3				90%
01-001-05-04-02-02	OUTER ROLL RING	7	1	0.206	0.229	2	0.229	3				90%
01-001-05-04-02-03	INNER ROLL RING	7	1	0.130	0.146	2	0.146	3				90%
01-001-05-04-02-04	ROLL GEAR	7	1	0.010	0.011	2	0.011	3				90%
01-001-05-04-02-05	TS P&C PLATFORM	7	1	0.047	0.053	2	0.053	3				90%
01-001-05-04-02-06	GIMBAL GM & L.L.	7	2	0.130	0.282	2	0.140	3				90%
01-001-05-04-03-00	ARRAY PLATFORM ASSY	6			0.632							
01-001-05-04-03-01	ARRAY MOUNT	7	1	0.308	0.351	2	0.351	3				90%
01-001-05-04-03-02	PLATFORM G.M. & L.L.	7	2	0.127	0.281	2	0.136	3				90%

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
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COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT	LEARN INDEX
01-001-05-04-04-00	SUPPORT EQUIP SET	6			0.528							
01-001-05-04-04-01	CMG SUPPORT	7	3	0.023	0.072	2	0.025	3				90%
01-001-05-04-04-02	WC X-RAY DET. MT.	7	2	0.119	0.253	2	0.128	3				90%
01-001-05-04-04-03	γ -RAY HOUS & EXTEN	7	1	0.186	0.203	2	0.203	3				90%
01-001-05-04-05-00	SOLAR TS HOUSING ASS	6			1.046							
01-001-05-04-05-01	TUBULAR STRUCT.	7	1	0.466	0.524	2	0.524	3				90%
01-001-05-04-05-02	BULKHEADS	7	2	0.203	0.444	2	0.218	3				90%
01-001-05-04-05-03	SUNSHIELD	7	1	0.047	0.053	2	0.053	3				90%
01-001-05-04-05-04	APERTURE DOORS	7	6	0.003	0.019	2	0.003	3				90%
01-001-05-04-05-05	DOOR ACTUATORS	7	6	0.001	0.006	2	0.001	3				90%
01-001-05-04-06-00	UV INSTRUMENT MOUNT	6			0.311							
01-001-05-04-06-01	AZ TABLE	7	1	0.055	0.060	2	0.060	3				90%
01-001-05-04-06-02	AZ YOKE	7	1	0.091	0.099	2	0.099	3				90%
01-001-05-04-06-03	LAUNCH LOCKS	7	1	0.046	0.049	2	0.049	3				90%
01-001-05-04-06-04	JETTISON EQUIP.	7	1	0.036	0.038	2	0.038	3				90%
01-001-05-04-06-05	AZ GEARMOTORS	7	1	0.048	0.051	2	0.051	3				90%
01-001-05-04-06-06	FITTINGS/FIXT.	7	1	0.013	0.014	2	0.014	3				90%

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COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT	LEARN INDEX
01-001-05-04-07-00	UV INST. PLATFORM	6			0.245							
01-001-05-04-07-01	EQUIP PLATFORM	7	2	0.004	0.008	2	0.004	3				90%
01-001-05-04-07-02	GIMBAL RING	7	1	0.052	0.059	2	0.059	3				90%
01-001-05-04-07-03	OUTER ROLL RING	7	1	0.069	0.078	2	0.078	3				90%
01-001-05-04-07-04	INNER ROLL RING	7	1	0.046	0.051	2	0.051	3				90%
01-001-05-04-07-05	PLAT. GEARMOTORS	7	1	0.026	0.029	2	0.029	3				90%
01-001-05-04-07-06	FITTINGS/FIXTURES	7	1	0.018	0.020	2	0.020	3				90%
01-001-05-05-00-00	ELECTRONICS	5			3.673				12	24	50/60	
01-001-05-05-01-00	CONTROL & DISPLAY	6	1	1.570	1.940	2	1.940	3				90%
01-001-05-05-02-00	ELECTRICAL	6			0.702							
01-001-05-05-02-01	LOAD CENTER SW	7	3	0.030	0.093	2	0.032	3				90%
01-001-05-05-02-02	FEEDER CABLES	7	1	0.500	0.543	2	0.543	3				90%
01-001-05-05-02-03	JUNCTION BOX	7	1	0.060	0.066	2	0.066	3				90%
01-001-05-05-03-00	DATA	6			0.405							
01-001-05-05-03-01	DATA BUS INTERFACE	7	2	0.020	0.042	2	0.021	3				90%
01-001-05-05-03-02	COAX DATA BUS	7	1	0.040	0.043	2	0.043	3				90%
01-001-05-05-03-03	PALLET INST. BOX	7	1	0.100	0.109	2	0.109	3				90%
01-001-05-05-03-04	DATA PROCESSOR	7	2	0.100	0.211	2	0.107	3				90%
01-001-05-05-04-00	UV INST. C&D	6	1	0.172	0.213	2	0.213	3				90%

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
CONTRACT NO. NAS8-28144

COST DATA FORM - A(2)

RECURRING (PRODUCTION)

DATE: MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT	LEARN INDEX
01-001-05-05-05-00	UV INST ELECTRICAL	6			0.108							
01-001-05-05-05-01	LOAD CENTER SW	7	1	0.030	0.032	2	0.032	3				90%
01-001-05-05-05-02	FEEDER CABLES	7	1	0.029	0.031	2	0.031	3				90%
01-001-05-05-05-03	JUNCTION BOX	7	1	0.042	0.045	2	0.045	3				90%
01-001-05-05-06-00	UV INST. DATA	6			0.305							
01-001-05-05-06-01	TELEMETRY	7	1	0.042	0.045	2	0.045	3				90%
01-001-05-05-06-02	PROGRAMMER	7	1	0.138	0.149	2	0.149	3				90%
01-001-05-05-06-03	MINI-COMPUTER	7	1	0.095	0.111	2	0.111	2				90%
01-001-05-06-00-00	THERMAL CONTROL	5			0.255				9	21		
01-001-05-06-01-00	THERMAL COATING	6	1	0.014	0.016	2	0.016	3			50/60	90%
01-001-05-06-02-00	MULTILAYER INSULATION	6	1	0.220	0.239	2	0.239	3			50/60	90%
01-001-05-07-00-00	SMALL UV INSTRUMENTS	5			18.104							
01-001-05-07-01-00	6-IN SURVEY CAMERAS	6	1	3.200	3.730	1	3.730	2	12	21		90%
01-001-05-07-02-00	ALL-REFL. SPECTROGR.	6	1	1.200	1.385	1	1.385	2	9	18		90%
01-001-05-07-03-00	10-CM IMAGE CONV. SPEC	6	1	1.200	1.385	1	1.385	2	9	18		90%
01-001-05-07-04-00	15-CM IMAGE CONV. SPEC	6	1	1.440	1.663	1	1.663	2	12	21		90%
01-001-05-07-05-00	40-CM INTERNAL GRAT.	6	1	3.200	3.696	1	3.696	2	12	21		90%
01-001-05-07-06-00	40-CM IMAGING CAMERA	6	1	3.200	3.696	1	3.696	2	12	21		90%
01-001-05-07-07-00	ECHELLE SPECTROG.	6	1	1.440	1.663	1	1.663	2	9	18		90%
01-001-05-07-08-00	SCANNING SPECTROM	6	1	0.750	0.886	1	0.886	2	12	21		90%

3. Cost Data Form - A(3) Recurring (Operations)

Two distinct elements of costs make up recurring (operations) costs: spares hardware; and operations manpower. The two have been estimated separately and are presented on Form - A(3) in separate groups.

The first element (spares) has been estimated for each candidate WBS item for a payload, WBS Identification Numbers 01-001-05-XX-XX-XX [pp 1 thru 7 of Form - A(3)].

The second element (operations) consists of four separate operations activities [pp 8 thru 11 of Form - A(3)] --

WBS Identification	WBS Identification Number
Launch	01-001-06-XX-XX-XX
Mission	01-001-07-XX-XX-XX
Support	01-001-08-XX-XX-XX
Recovery & Refurbishment	01-001-09-XX-XX-XX

A description of the contents of each column of Form - A(3) follows:

1) Identification Number - The 13-digit WBS number of the item of cost;

2) WBS Identification - The alphanumeric nomenclature of the item from the WBS;

3) WBS Level - The level at which the element is carried;

4) Number of Units - The quantity of units is not shown. A percentage (variable depending on the item and the expected failure or wearout rate) was applied to the production quantity to estimate spares per flight or mission (pp 1 thru 7). A quantity is not applicable for operations costs shown on pages 8 through 11;

5) Expected Cost - The cost estimate for the WBS item;

6) Reference Unit - Not applicable;

7) Reference Unit Cost - Not applicable;

8) Confidence Rating - A value of 1 through 4 representing the estimator's confidence in the estimate shown in WBS item cost column. The values were obtained by reviewing the criteria presented in the *Phase A and Phase B Studies Cost Estimates Document*, DRD No. MF-030A, Table 1, "Confidence Level Groups for Cost Estimates," selecting the value most applicable;

9) T_d - For recurring (operations), T_d is undefined since no flight schedule is defined;

10) T_s - For recurring (operations), T_s is undefined since no flight schedule is defined;

11) Spread Function - An index number representing a cost distribution curve that the estimator recommends for the time phasing of costs over T_d. Standard distributions from Figure 8 of the *Phase A and Phase B Studies Cost Estimates Document*, No. MF-030A, were used where applicable;

12) Learning Index - A numerical index of a learning rate related to the recurring cost.

a. Recurring (Operations) Hardware Spares (Pages 1 through 7) - Costs of spares for hardware elements for one flight or mission were estimated. The "Expected Cost" shown in Form - A(3) for spares is defined as follows:

EXPECTED COST = A + B + C + D.

Where:

A = SPARES HARDWARE, which was estimated as a percentage, depending on the item and the expected failure or wear-out rate, and applied to the FIRST UNIT COST T_1;

B = GSE, which was estimated as 25% of (A);

C = SUBSYSTEM SUPPORT, which was estimated as 11% of (A + B);

D = PROJECT MANAGEMENT, which was estimated as 7.6% of (A + B + C).

b. Recurring (Operations) for Launch Mission Support, and Recovery and Refurbishment (pp 8 thru 11) - Cost Estimates for the launch, mission, support, and recovery/refurbishment functions were based on the engineering, technical, and scientific manpower levels required to perform these operations. Associated (but still direct) support from laboratory personnel at the PIC and for interfacing with the Sortie Lab and pallet are included. Total direct manpower requirements were then adjusted for systems support and project management.

These cost estimates assume the functions are accomplished by the contractor at three separate locations. They further assume that government facilities such as buildings, utilities, office equipment, transportation, gases, and fluids are available at each location at no cost to the contractor.

"Expected Cost" as shown in Form - A(3) for these operations is defined as follows:

EXPECTED COST = A + B + C.

Where:

A = TOTAL DIRECT MANPOWER COST, which was estimated as the man-months required considering skill levels;

B = SYSTEMS SUPPORT, which was estimated as 11% of (A);

C = PROJECT MANAGEMENT, which was estimated as 7.6% of (A + B).

STUDY TITLE ASTRONOMY SORTIE MISSIONS DEFINITION STUDY
CONTRACT NO. NAS8-28144

COST DATA FORM – A (3)
RECURRING (OPERATIONS)

DATE MARCH 73

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECT. COST	REF. UNIT	REF UNIT COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.	LEARN. INDEX
01-001-05-00-00-00	PAYLOADS	4									
01-001-05-01-00-00	TELESCOPES	5		4.221							
01-001-05-01-01-00	IR TELESCOPE	6		0.538			2				90%
01-001-05-01-02-00	STRATOSCOPE III	6		0.967			2				90%
01-001-05-01-03-00	PHOTOHELIOGRAPH	6		1.033			2				90%
01-001-05-01-04-00	X-RAY TELESCOPE	6		1.101			2				90%
01-001-05-01-05-00	XUV SPECTROHELIOGRAPH	6		0.194			2				90%
01-001-05-01-06-00	CORONAGRAPHS	6		0.204			2				90%
01-001-05-01-07-00	MONITORS	6		0.184			2				90%
01-001-05-02-00-00	ARRAYS	5		8.808							
01-001-05-02-01-00	LARGE AREA X-RAY	6		2.661			2				90%
01-001-05-02-02-00	WC X-RAY	6		0.467			2				90%
01-001-05-02-03-00	LARGE MOD COLL	6		1.082			2				90%
01-001-05-02-04-00	N.B. SPECTROM	6		2.132			2				90%
01-001-05-02-05-00	COLL P.C. SPECTROM	6		*							
01-001-05-02-06-00	γ-RAY SPECTROM	6		2.466			2				90%
01-001-05-02-07-00	L.B. γ-RAY DETECT	6		**			2				
01-001-05-02-08-00	PROTON FLUX DETECT	6		N/A							

(*) INCLUDED IN LARGE AREA X-RAY
(**) INCLUDED IN γ-RAY SPECTROMETER

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01-001-05-03-00-00	POINT & CONTROL	5		0.307						50/60	
01-001-05-03-01-00	CMG ASSY	6		0.059							
01-001-05-03-01-01	DOUBLE GIM CMG'S	7		0.048			4				90%
01-001-05-03-01-02	INVERTERS	7		0.004			4				90%
01-001-05-03-01-03	IMU	7		0.007			3				90%
01-001-05-03-02-00	COMMON MOUNT ACT.	6		0.016							
01-001-05-03-02-01	AZ POINT	7		0.009			3				90%
01-001-05-03-02-02	DEPLOY	7		0.007			3				90%
01-001-05-03-03-00	TELESCOPE GIMBAL ACT.	6		0.036							
01-001-05-03-03-01	EL POINT & STAB	7		0.015			1				90%
01-001-05-03-03-02	AZ STABIL	7		0.009			1				90%
01-001-05-03-03-03	ROLL	7		0.006			3				90%
01-001-05-03-03-04	PITCH & YAW	7		0.006			3				90%
01-001-05-03-04-00	ARRAY PLATFORM ACT.	6		0.012							
01-001-05-03-04-01	EL POINTING	7		0.012			3				90%

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01-001-05-03-05-00	REFERENCE ASSY	6		0.135							
01-001-05-03-05-01	STRAPDOWN STAR TRK	7		0.051			1				
01-001-05-03-05-02	TELE. IMU	7		0.010			3				90%
01-001-05-03-05-03	FINE SUN SENSOR	7		0.030			4				90%
01-001-05-03-05-04	BS STAR TRACKER	7		0.012			3				90%
01-001-05-03-05-05	CORREL TRACKER	7		0.032			3				90%
01-001-05-03-06-00	UV GYRO PACKAGE	6		0.001			3				90%
01-001-05-03-07-00	UV OUTER GIM MT ACT	6		0.036			2				90%
01-001-05-03-07-01	EL POINT & STAB	7									
01-001-05-03-07-02	AZ STAB	7									
01-001-05-03-08-00	UV REF ASSY	6		0.012			2				90%
01-001-05-03-08-01	VIDICON CAMERA	7									
01-001-05-03-08-02	REF CAMERA	7									
01-001-05-03-08-03	SUN-EARTH SENSOR	7									
01-001-05-03-08-04	RADIATION DET.	7									

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECT COST	REF. UNIT	REF UNIT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT	LEARN. INDEX
01-001-05-04-00-00	STRUCTURES	5		0.198						50/60	
01-001-05-04-01-00	COMMON MOUNT ASSY	6		0.013							
01-001-05-04-01-01	AZ TABLE	7		0.003			3				90%
01-001-05-04-01-02	AZ YOKE	7		0.003			3				90%
01-001-05-04-01-03	DEPLOY YOKE	7		0.002			3				90%
01-001-05-04-01-04	DEP. GEAR M & L.L.	7		0.003			3				90%
01-001-05-04-01-05	JETTISON EQUIP.	7		0.002			3				90%
01-001-05-04-02-00	TELESCOPE GIM ASSY	6		0.044							
01-001-05-04-02-01	OUTER GIM RING	7		0.009			3				90%
01-001-05-04-02-02	OUTER ROLL RING	7		0.010			3				90%
01-001-05-04-02-03	INNER ROLL RING	7		0.007			3				90%
01-001-05-04-02-04	ROLL GEAR	7		0.002			3				90%
01-001-05-04-02-05	TS P&C PLATFORM	7		0.003			3				90%
01-001-05-04-02-06	GIM GEAR M & L.L.	7		0.013			3				90%
01-001-05-04-03-00	ARRAY PLATFORM ASSY	6		0.044							
01-001-05-04-03-01	ARRAY MOUNT	7		0.025			3				90%
01-001-05-04-03-02	PLAT. GM & L.L.	7		0.019			3				90%

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01-001-05-04-04-00	SUPPORT EQUIP. SET	6		0.012							
01-001-05-04-04-01	CMG SUPPORT	7		0.002			3				90%
01-001-05-04-04-02	WC X-RAY DET MT	7		0.006			3				90%
01-001-05-04-04-03	X-RAY HOUS. & EXT.	7		0.004			3				90%
01-001-05-04-05-00	SOLAR TS HOUSING ASSY	6		0.063							
01-001-05-04-05-01	TUBULAR STRUCT	7		0.030			3				90%
01-001-05-04-05-02	BULKHEADS	7		0.027			3				90%
01-001-05-04-05-03	SUNSHIELDS	7		0.003			3				90%
01-001-05-04-05-04	APERTURE DOORS	7		0.002			3				90%
01-001-05-04-05-05	DOOR ACTUATORS	7		0.001			3				90%
01-001-05-04-06-00	UV INSTRUMENT MOUNT	6		0.009			3				90%
01-001-05-04-06-01	AZ TABLE	7									
01-001-05-04-06-02	AZ YOKE	7									
01-001-05-04-06-03	LAUNCH LOCKS	7									
01-001-05-04-06-04	JETTISON EQUIP	7									
01-001-05-04-06-05	AZ GEARMOTORS	7									
01-001-05-04-06-06	FITTINGS/FIXTURES	7									

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01-001-05-04-07-00	UV INST. PLATFORM	6		0.013			3				90%
01-001-05-04-07-01	EQUIP PLATFORM	7									
01-001-05-04-07-02	GIMBAL RING	7									
01-001-05-04-07-03	OUTER ROLL RING	7									
01-001-05-04-07-04	INNER ROLL RING	7									
01-001-05-04-07-05	PLAT. GEARMOTORS	7									
01-001-05-04-07-06	FITTINGS/FIXTURES	7									
01-001-05-05-00-00	ELECTRONICS	5		0.053						50/60	
01-001-05-05-01-00	CONTROL & DISPLAY	6		0.031			3				90%
01-001-05-05-02-00	ELECTRICAL	6		0.005							
01-001-05-05-02-01	LOAD CENTER SWITCH	7		0.002			3				90%
01-001-05-05-02-02	FEEDER CABLES	7		0.002			3				90%
01-001-05-05-02-03	JUNCTION BOX	7		0.001			3				90%
01-001-05-05-03-00	DATA	6		0.008							
01-001-05-05-03-01	DATA BUS INTERFACE	7		0.002			3				90%
01-001-05-05-03-02	COAX DATA BUS	7		0.001			3				90%
01-001-05-05-03-03	PALLET INST. BOX	7		0.002			3				90%
01-001-05-05-03-04	DATA PROCESSOR	7		0.003			3				90%
01-001-05-05-04-00	UV INST C&D	6		0.003			3				90%

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECT COST	REF. UNIT	REF UNIT COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT	LEARN INDEX
01-001-05-05-05-00	UV INST ELECTRICAL	6		0.001			3				90%
01-001-05-05-05-01	LOAD CENTER SWITCH	7									
01-001-05-05-05-02	FEEDER CABLES	7									
01-001-05-05-05-03	JUNCTION BOX	7									
01-001-05-05-06-00	UV INST DATA	6		0.005			2				90%
01-001-05-05-06-01	TELEMETRY	7									
01-001-05-05-06-02	PROGRAMMER	7									
01-001-05-05-06-03	MINI-COMPUTER	7									
01-001-05-06-00-00	THERMAL CONTROL	5		0.002						50/60	90%
01-001-05-06-01-00	THERMAL COATING	6					3				
01-001-05-06-02-00	MULTILAYER INSULATION	6					3				
01-001-05-07-00-00	SMALL UV INSTRUMENTS	5		0.988							
01-001-05-07-01-00	6-IN SURVEY CAMERAS	6		0.243			2				90%
01-001-05-07-02-00	ALL-REFL SPECTROGRAPH	6		0.072			2				90%
01-001-05-07-03-00	10-CM IMAGE CONV SPEC	6		0.072			2				90%
01-001-05-07-04-00	15-CM IMAGE CONV SPEC	6		0.087			2				90%
01-001-05-07-05-00	40-CM INTERNAL GRATING	6		0.191			2				90%
01-001-05-07-06-00	40-CM IMAGING CAMERA	6		0.191			2				90%
01-001-05-07-07-00	ECHELLE SPECTROGRAPH	6		0.087			2				90%
01-001-05-07-08-00	SCANNING SPECTROM	6		0.045			2				90%

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECT COST	REF. UNIT	REF UNIT COST	CONFID RATING	T_c	T_s	SPREAD FUNCT	LEARN INDEX
01-001-06-00-00-00	LAUNCH OPERATIONS										
01-001-06-01-00-00	IR TELESCOPE	5		0.053			3				
01-001-06-02-00-00	STRATOSCOPE III	5		0.046			3				
01-001-06-03-00-00	PHOTOHELIOGRAPH	5		0.036			3				
01-001-06-04-00-00	SOLAR GROUP	5		0.051			3				
01-001-06-05-00-00	LARGE AREA X-RAY & CPCS	5		0.051			3				
01-001-06-06-00-00	W.C. X-RAY DETECTOR	5		0.022			3				
01-001-06-07-00-00	LARGE MODULATION COLL.	5		0.026			3				
01-001-06-08-00-00	N.B. SPECTRO/POLARIM	5		0.026			3				
01-001-06-09-00-00	γ-RAY SPEC & L.B. γ-RAY	5		0.037			3				
	DET										
01-001-06-10-00-00	UV INSTRUMENTS	5		0.018			3				
01-001-06-11-00-00	TELESCOPE SUBSYS	5		0.008			3				
01-001-06-12-00-00	ARRAY SUBSYS.	5		0.005			3				
01-001-06-13-00-00	UV SUBSYS.	5		0.005			3				
01-001-07-00-00-00	MISSION OPERATIONS										
01-001-07-01-00-00	IR TELESCOPE	5		0.017			3				
01-001-07-02-00-00	STRATOSCOPE III	5		0.014			3				
01-001-07-03-00-00	PHOTOHELIOGRAPH	5		0.011			3				
01-001-07-04-00-00	SOLAR GROUP	5		0.015			3				

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECT COST	REF. UNIT	REF UNIT COST	CONFID. RATING	T_d	T_s	SPREAD POINT	LEAD INDEX
01-001-07-05-00-00	LARGE AREA X-RAY & CPCS	5		0.015			3				N/A
01-001-07-06-00-00	WC X-RAY DETECTOR	5		0.008			3				
01-001-07-07-00-00	LG. MODUL. COLLIMATOR	5		0.009			3				
01-001-07-08-00-00	N.B. SPECT/POLARIM.	5		0.009			3				
01-001-07-09-00-00	γ-RAY SPEC & L.B. γ RAY DET	5		0.012			3				
01-001-07-10-00-00	UV INSTRUMENTS	5		0.007			3				
01-001-07-11-00-00	TELESCOPE SUBSYS	5		0.008			3				
01-001-07-12-00-00	ARRAY SUBSYS	5		0.005			3				
01-001-07-13-00-00	UV SUBSYS	5		0.005			3				
01-001-08-00-00-00	SUPPORT OPERATIONS	4									
01-001-08-01-00-00	IR TELESCOPE	5		0.159			3				
01-001-08-02-00-00	STRATOSCOPE III	5		0.133			3				
01-001-08-03-00-00	PHOTOHELIOGRAPH	5		0.100			3				
01-001-08-04-00-00	SOLAR GROUP	5		0.147			3				
01-001-08-05-00-00	LG AREA X-RAY & CPCS	5		0.145			3				
01-001-08-06-00-00	W.C. X-RAY DETECTOR	5		0.057			3				
01-001-08-07-00-00	LG. MODUL. COLLIMATOR	5		0.073			3				
01-001-08-08-00-00	N.B. SPEC/POLARIM	5		0.073			3				

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01-001-08-09-00-00	γ-RAY SPEC & L.B.	5		0.100			3				
	γ-RAY DET.										
01-001-08-10-00-00	UV INSTRUMENTS	5		0.048			3				
01-001-08-11-00-00	TELESCOPE SUBSYSTEMS	5		0.009			3				
01-001-08-12-00-00	ARRAY SUBSYSTEMS	5		0.006			3				
01-001-08-13-00-00	UV INST. SUBSYSTEMS	5		0.006			3				
01-001-09-00-00-00	RECOVERY & REFURBISH-	4									
	MENT OPERATIONS										
01-001-09-01-00-00	IR TELESCOPE	5		0.091			3				
01-001-09-02-00-00	STRATOSCOPE III	5		0.075			3				
01-001-09-03-00-00	PHOTOHELIOGRAPH	5		0.061			3				
01-001-09-04-00-00	SOLAR GROUP	5		0.098			3				
01-001-09-05-00-00	LG. AREA X-RAY & CPCS	5		0.073			3				
01-001-09-06-00-00	WC X-RAY DETECTOR	5		0.029			3				
01-001-09-07-00-00	LG MODUL COLLIMATOR	5		0.040			3				
01-001-09-08-00-00	N.B. SPECT/POLARIM	5		0.040			3				
01-001-09-09-00-00	γ-RAY SPEC & L.B.	5		0.055			3				
	γ-RAY DET										
01-001-09-10-00-00	UV INSTRUMENTS	5		0.025			3				
01-001-09-11-00-00	TELESCOPE SUBSYS	5		0.012			3				

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01-001-09-12-00-00	ARRAY SUBSYS	5		0.009			3				
01-001-09-03-00-00	UV SUBSYS	5		0.008			3				

C. COST ESTIMATES BY COMMON ITEMS, TELESCOPE, ARRAY GROUPS, AND INSTRUMENTS

Costs for DDT&E, recurring (production), and recurring (operations) have been tabulated for each WBS item, grouping the items according to application. In this grouping by use, the intermediate telescopes and array groups with their subsystems are considered separately from the small UV instruments and the subsystems required for them. The small UV instruments are unique and may be flown separately when an opportunity is available.

For the intermediate class telescopes and the array groups, items of subsystems equipment having some common use were assigned to one of four categories of commonality. These categories include portions of the various subsystems, but have the distinguishing characteristic of some use that is common to the entire payload, or to two or more Astronomy Sortie telescopes, or to telescopes and array groups, or to two or more array groups. Subsystem equipment that has no common application (i.e., is peculiar to a particular telescope or to one array group) was excluded from any of the "common" categories. The four "common" categories for the intermediate telescopes and array groups are as follows:

Category	Description
I	Common to Payloads
II	Common to Telescopes and Arrays
III	Common to Telescopes
IV	Common to Array Groups B, C, D, & E

The equipment lists, with costs, are shown in Table V-1 for these categories of common equipment.

The subsystem components and assemblies included in each of the "common" categories for the telescopes and arrays are as follows:

1) Category I - Equipment "Common to Payloads" includes the subsystem components and assemblies that must be provided in a Sortie Lab and pallet for any astronomy sortie mission. This equipment supports either an intermediate telescope or an array group or both. The distinguishing characteristic is

Table V-1 Subsystem Equipment and Operations

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
I	PAYLOAD COMMON	13.237	11.939	25.176	4.313	0.837	5.150	0.071	0.036	0.107
	POINTING & CONTROL (PARTIAL)									
01-001-05-03-01-00	CMG ASSEMBLY									
-01	DOUBLE GIMBAL CMGs	0.770	2.425	3.195	1.642	0.319	1.961	0.032	0.016	0.048
-02	INVERTERS	0.140	0.268	0.408	0.156	0.030	0.186	0.003	0.001	0.004
-03	IMU	0	0.330	0.330	0.239	0.046	0.285	0.005	0.002	0.007
	STRUCTURES (PARTIAL)									
	SUPPORT EQUIPMENT SET (PARTIAL)									
01-001-05-04-04-01	CMG SUPPORT STRUCTURE	0.168	0.147	0.315	0.060	0.012	0.072	0.001	0.001	0.002
	ELECTRONIC (PARTIAL)									
01-001-05-05-01-00	CONTROL & DISPLAY	7.710	5.755	13.465	1.625	0.315	1.940	0.021	0.010	0.031
	ELECTRICAL (PARTIAL)									
01-001-05-05-02-01	LOAD CENTER SWITCH	0.100	0.147	0.247	0.026	0.005	0.031	0.001	0.001	0.002
-02	FEEDER CABLES	0.519	0.322	0.841	0.026	0.005	0.031	0.001	0.001	0.002
-03	JUNCTION BOX	0.190	0.155	0.345	0.055	0.011	0.066	0.001	0	0.001
01-001-05-05-03-00	DATA									
-01	DATA BUS INTERFACE UNIT	0.060	0.075	0.135	0.035	0.007	0.042	0.001	0.001	0.002
-02	COAX DATA BUS	0.160	0.136	0.296	0.036	0.007	0.043	0.001	0	0.001
-03	PALLET INSTRUMENT BOX	0.550	0.383	0.933	0.091	0.018	0.109	0.001	0.001	0.002
-04	DATA PROCESSOR	0.550	0.501	1.051	0.177	0.034	0.211	0.002	0.001	0.003
01-001-05-06-00-00	THERMAL CONTROL	2.320	1.295	3.615						
01-001-05-06-02-00	MULTILAYER INSULATION (PARTIAL)				0.145	0.028	0.173	0.001	0.001	0.002

Table V-1 (cont)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
	POINTING & CONTROL (PARTIAL)									
01-001-05-03-02-00	COMMON MOUNT ACTUATORS									
-01	AZIMUTH POINTING	0.650	0.490	1.140	0.150	0.029	0.179	0.006	0.003	0.009
-02	DEPLOYMENT	0.670	0.462	1.132	0.122	0.024	0.146	0.005	0.002	0.007
	STRUCTURES (PARTIAL)									
01-001-05-04-01-00	COMMON MOUNT ASSEMBLY									
-01	AZIMUTH TABLE	0.870	0.615	1.485	0.155	0.030	0.185	0.002	0.001	0.003
-02	AZIMUTH YOKE	1.368	0.961	2.329	0.241	0.047	0.288	0.002	0.001	0.003
-03	DEPLOYMENT YOKE	0.603	0.424	1.027	0.106	0.021	0.127	0.001	0.001	0.002
-04	DEPLOYMENT GEARMOTORS & LAUNCH LOCKS	0.433	0.437	0.870	0.220	0.043	0.263	0.002	0.001	0.003
-05	JETTISON EQUIPMENT	0.163	0.114	0.277	0.029	0.006	0.035	0.001	0.001	0.002
	ELECTRONIC (PARTIAL)									
	ELECTRICAL (PARTIAL)									
01-001-05-05-02-01	LOAD CENTER SWITCH	N/A	N/A	N/A	0.052	0.010	0.062	0.001	0.001	0.002
-02	FEEDER CABLES	N/A	N/A	N/A	0.052	0.010	0.062	0.003	0.001	0.004
	THERMAL CONTROL									
01-001-05-06-01-00	THERMAL COATING (PARTIAL)	N/A	N/A	N/A	0.013	0.003	0.016	N/A	N/A	N/A

Table V-1 (cont)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING HARD-WARE	NON-RECURRING FLOAT-ING ITEMS	NON-RECURRING A(1) DDT&E	RECURRING (PRODUCTION) HARD-WARE	RECURRING (PRODUCTION) FLOAT-ING ITEMS	RECURRING (PRODUCTION) A(2) TOTAL	RECURRING (OPERATIONS) HARD-WARE	RECURRING (OPERATIONS) FLOAT-ING ITEMS	RECURRING (OPERATIONS) A(3) TOTAL
III	COMMON TO TELESCOPES	9.710	8.049	17.759	2.565	0.499	3.064	0.123	0.049	0.172
	POINTING & CONTROL (PARTIAL)									
01-001-05-03-03-00	TELESCOPE GIMBAL ACTUATORS									
-01	ELEVATION POINTING AND STABILITY	0.890	0.675	1.562	0.208	0.040	0.248	0.010	0.005	0.015
-02	AZIMUTH STABILITY	0.510	0.391	0.901	0.123	0.024	0.147	0.006	0.003	0.009
-03	ROLL	0.370	0.270	0.640	0.076	0.015	0.091	0.004	0.002	0.006
	REFERENCE ASSEMBLY (PARTIAL)									
01-001-05-03-05-01	STRAPDOWN STAR TRACKERS	1.960	2.537	4.497	1.169	0.227	1.396	0.034	0.017	0.051
-02	TELESCOPE IMU	2.720	1.693	4.413	0.241	0.047	0.288	0.007	0.003	0.010
	STRUCTURES (PARTIAL)									
01-001-05-04-02-00	TELESCOPE GIMBAL ASSEMBLY									
-01	OUTER GIMBAL RING	0.791	0.570	1.361	0.145	0.028	0.173	0.006	0.003	0.009
-02	OUTER ROLL RING	1.059	0.762	1.821	0.192	0.037	0.229	0.007	0.003	0.010
-03	INNER ROLL RING	0.670	0.481	1.151	0.122	0.024	0.146	0.005	0.002	0.007
-04	ROLL GEAR	0.050	0.037	0.087	0.009	0.002	0.011	0.001	0.001	0.002
-05	TELESCOPE P&C PLATFORM	0.241	0.155	0.396	0.004	0.009	0.053	0.002	0.001	0.003
-06	GIMBAL GM & LAUNCH LOCKS	0.449	0.478	0.927	0.236	0.046	0.282	0.009	0.004	0.013
	SUBSYSTEMS OPERATIONS									
01-001-06-11-00-00	LAUNCH							0.007	0.001	0.008
01-001-07-11-00-00	MISSION							0.007	0.001	0.008
01-001-08-11-00-00	SUPPORT							0.008	0.001	0.009
01-001-09-11-00-00	RECOVERY & REFURBISHMENT							0.010	0.002	0.012

Table V-1 (concl)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
IV	COMMON TO ARRAY GROUPS B, C, D, & E	2.456	1.735	4.191	0.861	0.168	1.029	0.060	0.024	0.084
	POINTING & CONTROL (PARTIAL)									
01-001-05-03-04-00	ARRAY PLATFORM ACTUATORS									
01-001-05-03-04-01	ELEVATION POINTING	0.570	0.434	1.004	0.132	0.026	0.158	0.008	0.004	0.012
	STRUCTURES (PARTIAL)									
01-001-05-04-03-00	ARRAY PLATFORM ASSEMBLY									
-01	ARRAY MOUNT	1.585	1.134	2.719	0.294	0.057	0.351	0.017	0.008	0.025
-02	PLATFORM GM & LAUNCH LOCKS	0.301	0.167	0.468	0.235	0.046	0.281	0.013	0.006	0.019
	THERMAL CONTROL	N/A						0.002	0.001	0.003
01-001-05-06-02-00	MULTILAYER INSULATION				0.200	0.039	0.239			
	SUBSYSTEMS OPERATIONS									
01-001-06-12-00-00	LAUNCH							0.004	0.001	0.005
01-001-07-12-00-00	MISSION							0.004	0.001	0.005
01-001-08-12-00-00	SUPPORT							0.005	0.001	0.006
01-001-09-12-00-00	RECOVERY & REFURBISHMENT							0.007	0.002	0.009

that the equipment is necessary for any of the Astronomy Sortie missions, regardless of telescope and array group complement.

2) Category II - "Common to Telescopes and Arrays" includes the subsystem equipment that must be provided for each intermediate telescope and/or for each array group. This equipment is mainly the common mount and peripherial equipment. Equipment that is specifically for the telescopes is excluded here and is Category III. Equipment that is specifically for the array groups is also excluded and is Category IV.

3) Category III - "Common to Telescopes" includes the subsystem equipment that must be provided for any of the intermediate telescopes (or the solar group). This is mainly equipment used on, or in conjunction with, the common mount to accommodate the telescopes or to support telescope operations. Specifically excluded from this "common" grouping is equipment required only for array groups B, C, D, and E.

4) Category IV - "Common to Array Groups B, C, D, and E" includes the subsystem equipment that must be provided for any of the array groups B, C, D, and E. This is mainly equipment used on, or in conjunction with, the common mount to accommodate the array groups, or to support array operations. Array Group A equipment is not common to the other array groups and is listed separately on summary sheets as peculiar equipment.

Subsystem equipment for the small UV instruments is common to all of the instruments considered and to the two groups of these instruments. The two groups are the three ST-100 instruments (Group A) and the two complementary 40-centimeter Carruthers instruments (Group B). The common equipment for these instruments was grouped as Category V "Common to UV Instruments." The equipment lists, with costs, are shown in Table V-2.

Table V-2 UV Instruments Subsystems Equipment

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING HARD-WARE	NON-RECURRING FLOAT-ING ITEMS	NON-RECURRING A(1) DDT&E	RECURRING (PRODUCTION) HARD-WARE	RECURRING (PRODUCTION) FLOAT-ING ITEMS	RECURRING (PRODUCTION) A(2) TOTAL	RECURRING (OPERATIONS) HARD-WARE	RECURRING (OPERATIONS) FLOAT-ING ITEMS	RECURRING (OPERATIONS) A(3) TOTAL
V	COMMON TO SMALL UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	POINTING & CONTROL (PARTIAL)	1.438	1.632	3.070	0.810	0.157	0.967	0.033	0.016	0.049
01-001-05-03-06-00	UV GYRO PACKAGE	0.070	0.041	0.111	0.010	0.002	0.012	0.001	0	0.001
01-001-05-03-07-00	UV OUTER GIM MOUNT ACTUATORS							0.024	0.012	0.036
-01	ELEV POINT & STABILITY	0.505	0.611	1.116	0.293	0.057	0.350	0.014		
-02	AZIMUTH STABILITY	0.309	0.399	0.708	0.202	0.039	0.241	0.010		
01-001-05-03-08-00	UV REFERENCE ASSEMBLY							0.008	0.004	0.012
-01	VIDICON CAMERA	0.243	0.260	0.503	0.139	0.027	0.166	0.004		
-02	REFERENCE CAMERA	0.129	0.137	0.266	0.074	0.014	0.088	0.002		
-03	SUN-EARTH SENSOR	0.091	0.092	0.183	0.046	0.009	0.055	0.001		
-04	RADIATION DETECTOR	0.091	0.092	0.183	0.046	0.009	0.055	0.001		
	STRUCTURES (PARTIAL)	4.371	2.775	7.146	0.466	0.090	0.556	0.015	0.007	0.022
01-001-05-04-06-00	UV INSTRUMENT MOUNT ASSY							0.006	0.003	0.009
-01	AZIMUTH TABLE	0.517	0.326	0.843	0.050	0.010	0.060	0.001		
-02	AZIMUTH YOKE	0.860	0.541	1.401	0.083	0.016	0.099	0.001		
-03	LAUNCH LOCKS	0.487	0.282	0.769	0.041	0.008	0.049	0.001		
-04	JETTISON EQUIPMENT	0.338	0.211	0.549	0.032	0.006	0.038	0.001		
-05	AZIMUTH GEARMOTORS	0.174	0.132	0.306	0.043	0.008	0.051	0.001		
-06	FITTINGS & FIXTURES	0.120	0.076	0.196	0.012	0.002	0.014	0.001		
01-001-05-04-07-00	UV INSTRUMENT PLATFORM							0.009	0.004	0.013
-01	EQUIPMENT PLATFORM	0.034	0.026	0.060	0.007	0.001	0.008	0		
-02	GIMBAL RING	0.489	0.311	0.800	0.049	0.010	0.059	0.002		
-03	OUTER ROLL RING	0.655	0.415	1.070	0.065	0.013	0.078	0.003		
-04	INNER ROLL RING	0.436	0.276	0.712	0.043	0.008	0.051	0.002		
-05	PLATFORM GEARMOTORS	0.095	0.073	0.168	0.024	0.005	0.029	0.001		
-06	FITTINGS & FIXTURES	0.166	0.106	0.272	0.017	0.003	0.020	0.001		

Table V-2 (Concl)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING HARD-WARE	NON-RECURRING FLOAT-ING ITEMS	NON-RECURRING A(1) DDT&E	RECURRING (PRODUCTION) HARD-WARE	RECURRING (PRODUCTION) FLOAT-ING ITEMS	RECURRING (PRODUCTION) A(2) TOTAL	RECURRING (OPERATIONS) HARD-WARE	RECURRING (OPERATIONS) FLOAT-ING ITEMS	RECURRING (OPERATIONS) A(3) TOTAL
V (CONTINUED)	COMMON TO SMALL UV INSTRUMENTS (CONTINUED)									
	ELECTRONIC (PARTIAL)	1.875	1.506	3.381	0.525	0.101	0.626	0.006	0.003	0.009
01-001-05-05-04-00	UV INST CONTROL & DISPLAY	0.845	0.630	1.475	0.178	0.035	0.213	0.002	0.001	0.003
01-001-05-05-05-00	UV INSTRUMENT ELECTRICAL							0.001	0	0.001
-01	LOAD CENTER SWITCH	0.067	0.061	0.128	0.027	0.005	0.032	0		
-02	FEEDER CABLES	0.152	0.106	0.258	0.026	0.005	0.031	0		
-03	JUNCTION BOX	0.111	0.094	0.205	0.038	0.007	0.045	0.001		
01-001-05-05-06-00	UV INSTRUMENT DATA							0.003	0.002	0.005
-01	TELEMETRY	0.100	0.090	0.190	0.038	0.007	0.045	0.001		
-02	PROGRAMMER	0.350	0.303	0.653	0.125	0.024	0.149	0.001		
-03	MINI-COMPUTER	0.250	0.222	0.472	0.093	0.018	0.111	0.001		
	UV SUBSYSTEM OPERATIONS							0.020	0.004	0.024
01-001-06-13-00-00	LAUNCH							0.004	0.001	0.005
01-001-07-13-00-00	MISSION							0.004	0.001	0.005
01-001-08-13-00-00	SUPPORT							0.005	0.001	0.006
01-001-09-13-00-00	RECOVERY & REFURBISHMENT							0.007	0.001	0.008
	UV INSTRUMENT OPERATIONS							0.083	0.016	0.099
01-001-06-10-00-00	LAUNCH							0.016	0.003	0.018
01-001-07-10-00-00	MISSION							0.005	0.002	0.007
01-001-08-10-00-00	SUPPORT							0.041	0.007	0.048
01-001-09-10-00-00	RECOVERY & REFURBISHMENT							0.021	0.004	0.025

Tabulations were then prepared from the appropriate "common" categories of equipment (adding any peculiar equipment) for each intermediate telescope, each array group, and the UV instruments. In these tabulations, the costs for each telescope, array group, and UV instrument are summarized, and the detail of DDT&E, Recurring (Production), and Recurring (Operations) is presented. For the total cost of the first flight, DDT&E plus Recurring (Production) are required. For follow-on flights only Recurring (Operations) costs are incurred.

These data are presented in Table V-3 for the intermediate telescopes, Table V-4 for the array groups, and Table V-5 for the small UV instruments.

Table V-3 IR Telescope, Stratoscope III, and Photoheliograph

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
	TOTAL IR TELESCOPE	40.384	26.045	66.429	21.132	3.023	24.155	0.867	0.339	1.206
01-001-05-01-01-00	IR TELESCOPE	10.500	1.155	11.655	12.360	1.360	13.720	0.360	0.178	0.538
01-001-05-01-07-00	MONITOR (IR)	0.050	0.006	0.056	0.494	0.054	0.548	0.014	0.008	0.022
I	PAYLOAD COMMON	13.237	11.939	25.176	4.313	0.837	5.150	0.071	0.036	0.107
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
III	COMMON TO TELESCOPES	9.710	8.049	17.759	2.565	0.499	3.064	0.123	0.049	0.172
01-001-05-03-05-04	PRECISION BS STAR TRACKER	2.130	1.393	3.523	0.260	0.050	0.310	0.008	0.004	0.012
	TELESCOPE OPERATIONS									
01-001-06-01-00-00	LAUNCH							0.044	0.009	0.053
01-001-07-01-00-00	MISSION							0.014	0.003	0.017
01-001-08-01-00-00	SUPPORT							0.133	0.026	0.159
01-001-09-01-00-00	RECOVERY & REFURBISHMENT							0.007	0.014	0.091
	TOTAL STRATOSCOPE III	36.104	24.415	60.519	15.866	2.422	18.288	1.091	0.458	1.549
01-001-05-01-02-00	STRATOSCOPE III	8.400	0.924	9.324	7.848	0.863	8.711	0.648	0.319	0.967
I	PAYLOAD COMMON	13.237	11.939	25.176	4.313	0.837	5.150	0.071	0.036	0.107
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
III	COMMON TO TELESCOPES	9.710	8.049	17.759	2.565	0.499	3.064	0.123	0.049	0.172
	TELESCOPE OPERATIONS									
01-001-06-02-00-00	LAUNCH							0.039	0.007	0.046
01-001-07-02-00-00	MISSION							0.012	0.002	0.014
01-001-08-02-00-00	SUPPORT							0.112	0.021	0.133
01-001-09-02-00-00	RECOVERY & REFURBISHMENT							0.063	0.012	0.075

Table V-3 (cont)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
	TOTAL PHOTOHELIOGRAPH	32.864	24.059	56.923	13.320	2.092	15.462	1.083	0.472	1.555
01-001-05-01-03-00	PHOTOHELIOGRAPH	5.160	0.568	5.728	5.302	0.583	5.885	0.692	0.341	1.033
I	PAYLOAD COMMON	13.237	11.939	25.176	4.313	0.837	5.150	0.071	0.036	0.107
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
III	COMMON TO TELESCOPES	9.710	8.049	17.759	2.565	0.449	3.064	0.123	0.049	0.172
	TELESCOPE OPERATIONS									
01-001-06-03-00-00	LAUNCH							0.030	0.006	0.036
01-001-07-03-00-00	MISSION							0.009	0.002	0.011
01-001-08-03-00-00	SUPPORT							0.084	0.016	0.100
01-001-09-03-00-00	RECOVERY & REFURBISHMENT							0.051	0.010	0.061

Table V-3 (concl)

SOLAR GROUP - MUST FLY WITH PHOTOHELIOGRAPH

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
	TOTAL SOLAR GROUP	47.898	22.015	69.913	20.053	2.734	22.787	1.610	0.706	2.316
01-001-05-01-04-00	X-RAY TELESCOPE	17.650	1.942	19.592	8.938	0.983	9.921	0.738	0.363	1.101
01-001-05-01-05-00	XUV SPECTROHELIOGRAPH	2.150	0.237	2.387	1.130	0.124	1.254	0.130	0.064	0.194
01-001-05-01-06-00	CORONAGRAPHS	2.980	0.329	3.309	2.087	0.230	2.317	0.137	0.067	0.204
01-001-05-01-07-00	MONITORS (SOLAR GROUP)	0.150	0.017	0.167	1.648	0.181	1.829	0.108	0.054	0.162
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
III	COMMON TO TELESCOPES	9.710	8.049	17.759	2.565	0.499	3.064	0.123	0.049	0.172
01-001-05-03-03-04	PITCH & YAW ACTUATORS	0.390	0.281	0.671	0.076	0.015	0.091	0.004	0.002	0.006
01-001-05-03-05-03	FINE SUN SENSOR	0.900	1.125	2.025	0.686	0.133	0.819	0.020	0.010	0.030
01-001-05-03-05-05	CORRELATION TRACKER	5.490	3.620	9.110	0.705	0.137	0.842	0.021	0.011	0.032
01-001-05-04-05-00	SOLAR TELESCOPES HOUSING ASSY									
01	TUBULAR STRUCTURE	2.395	1.705	4.100	0.439	0.085	0.524	0.020	0.010	0.030
02	BULKHEADS	1.045	0.994	2.039	0.372	0.072	0.444	0.018	0.009	0.027
03	FIBERGLASS SUNSHIELD	0.241	0.171	0.412	0.044	0.009	0.053	0.002	0.001	0.003
04	APERTURE DOORS	0.029	0.032	0.061	0.016	0.003	0.019	0.001	0.001	0.002
05	DOOR ACTUATORS	0.011	0.010	0.021	0.005	0.001	0.006	0.001	0	0.001
01-001-05-05-02-01	LOAD CENTER SWITCH	N/A			0.026	0.005	0.031	0.001	0.001	0.002
02	FEEDER CABLES	N/A			0.026	0.005	0.031	0.002	0.001	0.003
01-001-05-06-02-00	THERMAL INSULATION	N/A			0.150	0.029	0.179	0.001	0	0.001
	TELESCOPE OPERATIONS									
01-001-06-04-00-00	LAUNCH							0.042	0.009	0.051
01-001-07-04-00-00	MISSION							0.013	0.002	0.015
01-001-08-04-00-00	SUPPORT							0.123	0.024	0.147
01-001-09-04-00-00	RECOVERY & REFURBISHMENT							0.082	0.016	0.098

Table V-4 Array Groups A, B, C, D & E
(each must fly with the IR telescope or with stratoscope III)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING HARD-WARE	NON-RECURRING FLOAT-ING ITEMS	NON-RECURRING A(1) DDT&E	RECURRING (PRODUCTION) HARD-WARE	RECURRING (PRODUCTION) FLOAT-ING ITEMS	RECURRING (PRODUCTION) A(2) TOTAL	RECURRING (OPERATIONS) HARD-WARE	RECURRING (OPERATIONS) FLOAT-ING ITEMS	RECURRING (OPERATIONS) A(3) TOTAL
	TOTAL GROUP A	2.862	0.819	3.681	8.435	0.954	9.389	0.415	0.179	0.594
	GROUP A									
01-001-05-02-02-00	WIDE COV X-RAY DETECTOR	2.250	0.248	2.498	8.112	0.892	9.004	0.312	0.155	0.467
01-001-05-02-08-00	PROTON FLUX DETECTOR	0	0	0	0	0	0	0	0	0
01-001-05-04-01-05	JETTISON EQUIPMENT	N/A			0.057	0.011	0.068	0.001	0.001	0.002
01-001-05-04-04-02	WC X-RAY DETECTOR MOUNT	0.612	0.571	1.183	0.212	0.041	0.253	0.004	0.002	0.006
01-001-05-05-02-01	LOAD CENTER SWITCH	N/A			0.027	0.005	0.032	0.001	0	0.001
01-001-05-05-02-02	FEEDER CABLES	N/A			0.027	0.005	0.032	0.001	0.001	0.002
	ARRAY OPERATIONS									
01-001-06-06-00-00	LAUNCH							0.018	0.004	0.022
01-001-07-06-00-00	MISSION							0.006	0.002	0.008
01-001-08-06-00-00	SUPPORT							0.048	0.009	0.057
01-001-09-06-00-00	RECOVERY & REFURBISHMENT							0.024	0.005	0.029
	TOTAL GROUP B	13.513	5.931	19.444	13.629	1.670	15.299	1.634	0.765	2.399
	GROUP B									
01-001-05-02-04-00	NARROW BAND SPECT/POLAR	6.300	0.693	6.993	11.628	1.279	12.907	1.428	0.704	2.132
01-001-05-02-08-00	PROTON FLUX DETECTOR	0	0	0	0	0	0	0	0	0
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
IV	COMMON TO ARRAY GROUPS B, C, D, & E	2.456	1.735	4.191	0.861	0.168	1.029	0.060	0.024	0.084
	ARRAY OPERATIONS									
01-001-06-08-00-00	LAUNCH							0.022	0.004	0.026
01-001-07-08-00-00	MISSION							0.007	0.002	0.009
01-001-08-08-00-00	SUPPORT							0.061	0.012	0.073
01-001-09-08-00-00	RECOVERY & REFURBISHMENT							0.033	0.007	0.040

Table V-4 (cont)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING HARD-WARE	NON-RECURRING FLOAT-ING ITEMS	NON-RECURRING A(1) DDT&E	RECURRING (PRODUCTION) HARD-WARE	RECURRING (PRODUCTION) FLOAT-ING ITEMS	RECURRING (PRODUCTION) A(2) TOTAL	RECURRING (OPERATIONS) HARD-WARE	RECURRING (OPERATIONS) FLOAT-ING ITEMS	RECURRING (OPERATIONS) A(3) TOTAL
	TOTAL GROUP C	21.968	7.428	29.396	15.623	1.903	17.526	1.910	0.883	2.793
	GROUP C									
01-001-05-02-06-00	GAMMA RAY SPECTROMETER &	7.300	0.803	8.103	5.130	0.564	5.694	1.652	0.814	2.466
01-001-05-02-07-00	LOW BACKGROUND GAMMA RAY DET	6.500	0.715	7.215	8.322	0.915	9.237			
01-001-05-02-08-00	PROTON FLUX DETECTOR	0	0	0	0	0	0	0	0	0
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
IV	COMMON TO ARRAY GROUPS B, C, D, & E	2,456	1.735	4.191	0.861	0.168	1.029	0.060	0.024	0.084
01-001-05-04-04-03	GAMMA RAY SPECT HOUS & EXT MECHANISM	0.955	0.672	1.627	0.170	0.033	0.203	0.003	0.001	0.004
	ARRAY OPERATIONS									
01-001-06-09-00-00	LAUNCH							0.031	0.006	0.037
01-001-07-09-00-00	MISSION							0.010	0.002	0.012
01-001-08-09-00-00	SUPPORT							0.085	0.015	0.100
01-001-09-09-00-00	RECOVERY & REFURBISHMENT							0.046	0.009	0.055
	TOTAL GROUP D	14.163	6.003	20.166	7.906	1.041	8.947	0.931	0.418	1.349
	GROUP D									
01-001-05-02-03-00	LARGE MODULATION COLLIMATOR	6.950	0.765	7.715	5.905	0.650	6.555	0.725	0.357	1.082
01-001-05-02-08-00	PROTON FLUX DETECTOR	0	0	0	0	0	0	0	0	0
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
IV	COMMON TO ARRAY GROUPS B, C, D, & E	2.456	1.735	4.191	0.861	0.168	1.029	0.060	0.024	0.084
	ARRAY OPERATIONS									
01-001-06-07-00-00	LAUNCH							0.022	0.004	0.026
01-001-07-07-00-00	MISSION							0.007	0.002	0.009
01-001-08-07-00-00	SUPPORT							0.061	0.012	0.073
01-001-09-07-00-00	RECOVERY & REFURBISHMENT							0.033	0.007	0.040

Table V-4 (concl)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
	TOTAL GROUP E	17.263	6.344	23.607	15.663	1.893	17.556	2.103	0.961	3.064
	GROUP E									
01-001-05-02-01-00	LARGE AREA X-RAY DETECTOR &	4.950	0.545	5.495	5.267	0.579	5.846	1.782	0.879	2.661
01-001-05-02-05-00	COLLIMATED PC SPECTROMETER	5.100	0.561	5.661	8.395	0.923	9.318			
01-001-05-02-08-00	PROTON FLUX DETECTOR	0	0	0	0	0	0	0	0	0
II	COMMON TO TELESCOPES & ARRAYS	4.757	3.503	8.260	1.140	0.223	1.363	0.023	0.012	0.035
IV	COMMON TO ARRAY GROUPS B, C, D, & E	2.456	1.735	4.191	0.861	0.168	1.029	0.060	0.024	0.084
	ARRAY OPERATIONS									
01-001-06-05-00-00	LAUNCH							0.042	0.009	0.051
01-001-07-05-00-00	MISSION							0.013	0.002	0.015
01-001-08-05-00-00	SUPPORT							0.122	0.023	0.145
01-001-09-05-00-00	RECOVERY & REFURBISHMENT							0.061	0.012	0.073

Table V-5 Small UV Instruments and UV Instrument Groups

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING			RECURRING (PRODUCTION)			RECURRING (OPERATIONS)		
		HARD-WARE	FLOAT-ING ITEMS	A(1) DDT&E	HARD-WARE	FLOAT-ING ITEMS	A(2) TOTAL	HARD-WARE	FLOAT-ING ITEMS	A(3) TOTAL
01-001-05-07-00-00	SMALL UV INSTRUMENTS									
	TOTAL-INSTRUMENT & SUBSYSTEMS	9.484	6.111	15.595	5.161	0.718	5.879	0.320	0.126	0.446
01-001-05-07-01-00	SIX-INCH SURVEY CAMERAS (TIFFT)	1.800	0.198	1.998	3.360	0.370	3.730	0.163	0.080	0.243
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	TOTAL-INSTRUMENT & SUBSYSTEMS	8.384	5.990	14.374	3.049	0.485	3.534	0.205	0.070	0.275
01-001-05-07-02-00	ALL-REFLECTIVE SPECT (MORTON)	0.700	0.077	0.777	1.248	0.137	1.385	0.048	0.024	0.072
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.811	0.348	2.149	0.157	0.046	0.203
	TOTAL-INSTRUMENT & SUBSYSTEMS	8.384	5.990	14.374	3.049	0.485	3.534	0.205	0.070	0.275
01-001-05-07-03-00	10-CM IMAGE CONV SPECT (CARRUTHERS)	0.700	0.077	0.777	1.248	0.137	1.385	0.048	0.024	0.072
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	TOTAL-INSTRUMENT & SUBSYSTEMS	8.524	6.005	14.529	3.299	0.513	3.812	0.215	0.075	0.290
01-001-05-07-04-00	15-CM IMAGE CONV SPECT (CARRUTHERS)	0.840	0.092	0.932	1.498	0.165	1.663	0.058	0.029	0.087
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	TOTAL-INSTRUMENT & SUBSYSTEMS	9.484	6.111	15.595	5.131	0.714	5.845	0.285	0.109	0.394
01-001-05-07-05-00	40-CM INTERNAL GRAT SPECT (CARRUTHERS)	1.800	0.198	1.998	3.330	0.366	3.696	0.128	0.063	0.191
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	TOTAL-INSTRUMENT & SUBSYSTEMS	9.484	6.111	15.595	5.131	0.714	5.845	0.285	0.109	0.394
01-001-05-07-06-00	40-CM IMAGING CAMERA (CARRUTHERS)	1.800	0.198	1.998	3.330	0.366	3.696	0.128	0.063	0.191
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203

Table V-5 (concl)

WBS OR COMMON CATEGORY NUMBER	DESCRIPTION	NON-RECURRING HARD-WARE	NON-RECURRING FLOAT-ING ITEMS	NON-RECURRING A(1) DDT&E	RECURRING (PRODUCTION) HARD-WARE	RECURRING (PRODUCTION) FLOAT-ING ITEMS	RECURRING (PRODUCTION) A(2) TOTAL	RECURRING (OPERATIONS) HARD-WARE	RECURRING (OPERATIONS) FLOAT-ING ITEMS	RECURRING (OPERATIONS) A(3) TOTAL
	TOTAL INSTRUMENT & SUBSYSTEMS	8.524	6.005	14.529	3.299	0.513	3.812	0.215	0.075	0.290
01-001-05-07-07-00	ECHELLE SPECTROGRAPH (MORTON)	0.840	0.092	0.932	1.498	0.165	1.663	0.058	0.029	0.087
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	TOTAL INSTRUMENT & SUBSYSTEMS	7.684	5.913	13.597	2.581	0.434	3.015	0.187	0.061	0.248
01-001-05-07-08-00	SCANNING SPECTROMETER (KONDO)	0	0	0	0.780	0.086	0.866	0.030	0.015	0.045
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	ST-100 GROUP A TOTAL	10.884	6.265	17.149	7.657	0.992	8.649	0.565	0.249	0.814
01-001-05-07-01-00	SIX-INCH SURVEY CAMERAS (TIFFT)	1.800	0.198	1.998	3.36	0.370	3.730	0.163	0.080	0.243
-02-00	ALL-REFLECTIVE SPECT (MORTON)	0.700	0.077	0.777	1.248	0.137	1.385	0.048	0.024	0.072
-03-00	10-CM IMAGE CONV SPECT (CARRUTHERS)	0.700	0.077	0.777	1.248	0.137	1.385	0.048	0.024	0.072
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203
	ADDED INSTRUMENT OPERATIONS							0.149	0.075	0.224
	GROUP B TOTAL	11.284	6.309	17.593	8.461	1.080	9.541	0.413	0.172	0.585
01-001-05-07-06-00	40-CM INTERNAL GRAT SPECT (CARRUTHERS)	1.800	0.198	1.998	3.330	0.366	3.696	0.128	0.063	0.191
-07-00	40-CM IMAGING CAMERA (CARRUTHERS)	1.800	0.198	1.998	3.330	0.366	3.696	0.128	0.063	0.191
V	COMMON TO UV INSTRUMENTS	7.684	5.913	13.597	1.801	0.348	2.149	0.157	0.046	0.203

D. TECHNICAL CHARACTERISTICS DATA

Technical Characteristics Data (TCD) Form B sheets were prepared for each of the telescopes, arrays, and subsystems at WBS levels 5 and 6. The TCDs are arranged here in order of increasing number. The data were used in estimating costs of each item. A description of the information in each column of the TCD form is as follows:

1) WBS Identification Number - The 13-digit WBS code number of the item;

2) WBS Identification - The alphanumeric nomenclature of the item from the WBS;

3) Quantity or Value - The numerical quantity or value of the characteristic (Column 5) under consideration. Where no characteristic is identified, quantity refers to the WBS item and identification number;

4) Units of Measure - The identification of the units of measure associated with the characteristics (Column 5) under consideration. Where no characteristic is identified, units of measure applies to the WBS item and identification number;

5) Characteristics - The identification of the technical property under consideration;

6) Notes - Comments or explanations to clarify any of the information presented.

STUDY TITLE ASTRONOMY SORTIE MISSION DEFINITION STUDY
CONTRACT NO. NAS8-28144

TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 5

DATE MARCH 1973

WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-01-00-00	TELESCOPES	1	UNIT	1-m INFRARED TELESCOPE	
		1	UNIT	1.2-m STRATOSCOPE III	
		1	UNIT	1-m PHOTOHELIOGRAPH	
		1	UNIT	0.32-m X-RAY TELESCOPE	
		1	UNIT	0.25-m X UV SPECTROHELIOGRAPH	
		1	UNIT	CORONAGRAPH ASSEMBLY (2.5-cm AND 4.0-cm CORONAGRAPHS)	
		4	UNITS	MONITORS	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-01-00	INFRARED TELESCOPE	1.0	m	PRIMARY APERTURE	CASSEGRAIN OPTICS
		5.0	min	FIELD OF VIEW	
		f/10	-	SYSTEM F NUMBER	
		0.7-1000	MICRONS	WAVELENGTH RANGE	
		1	UNIT	INTERFEROMETER	
		1	UNIT	LINEAR DETECTOR ARRAY	
		3.2X1.6D	m	SIZE	
		1600 (3525)	kg (LB)	TOTAL WEIGHT	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-02-00	STRATOSCOPE III	1.20	m	PRIMARY APERTURE	RITCHEY-CHRETION
		6.0	MIN	FIELD OF VIEW	(WITH 2X RELAY)
		1.1	-	PRIMARY f NUMBER	
		1.2	-	SYSTEM f NUMBER	
		900 TO 20,000	ANGSTROMS	SPECTRAL RANGE	
		2	UNIT	FIELD CAMERAS	2 OR 3 SENSORS PER MISSION
		2	UNIT	SPECTROGRAPHS	
		1	UNIT	POLARIMETER	
		1	UNIT	FIELD VIEWING MONITOR	
		1	UNIT	INTERNAL CLOSED-LOOP GUIDING SYSTEM	
		4.2X1.9D	m	SIZE	
		(5.9X 1.9D)	(m)	(SUN SHADE EXTENDED)	
		1800 (3962)	kg (lb)	TOTAL WEIGHT	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-03-00	PHOTOHELIOGRAPH	1.0	m	PRIMARY APERTURL	GREGORIAN OPTICS
		3.0	$\overset{\frown}{\text{MIN}}$	FIELD OF VIEW	
		3.85	-	PRIMARY f NUMBER	
		50.0	-	OVERALL f NUMBER	
		2000 TO 7000	ANG-STROMS	SPECTRAL RANGE	
		3	UNIT	FILM CAMERAS	
		1	UNIT	SPECTROGRAPH	
		1	UNIT	INTERNAL FINE POINTING AND STABILITY SYSTEM	THE INTERNAL POINTING AND STABILIZATION SYSTEM WILL BE A SIGNIFICANT DE-VELOPMENT ITEM
		4.6X1.9 X1.42	m	SIZE	
		570	kg	TOTAL WEIGHT	
		(1260)	(1b)		

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-04-00	X-RAY TELESCOPE	32	cm	APERTURE	GRAZING INCIDENCE
		10	MIN	FIELD OF VIEW	
		10	-	OVERALL f NUMBER	
		2 TO 100	ANGSTROMS	SPECTRAL RANGE	
		1	UNIT	IMAGING SYSTEM	
		1	UNIT	CRYSTAL SPECTROMETER	
		1	UNIT	PROPORTIONAL COUNTER	
		1	UNIT	FILM CAMERA	
		4.6X0.7D	m	SIZE	
		392 (862)	kg (lb)	TOTAL WEIGHT	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-05-00	XUV SPECTROHELIOGRAPH	25	cm	APERTURE	CONCAVE GRATING-COLLECTING OPTICS
		32	MIN	FIELD OF VIEW	
		12	-	SYSTEM f NUMBER	
		170 TO 650	ANG-STROMS	SPECTRAL RANGE	
		1	UNIT	FILM CAMERA	
		3.4X1.3 X0.76			
		430 (948)	kg (lb)	TOTAL WEIGHT	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-06-00	CORONAGRAPHS	IC / OC			
	IC-INNER CORONAGRAPH	2.45/4.0	cm	APERTURE(S)	REFRACTIVE OPTICS
	OC-OUTER CORONAGRAPH				
		3.25/15	deg	FIELD OF VIEW	
		12.9/ 2.25	-	SYSTEM f NUMBER	
		4000 TO 7000	ANG-STROMS	SPECTRAL RANGE	
		2	UNIT	FILM CAMERAS	
		3.8X1.2X 0.7	m	SIZE	
		430	kg	TOTAL WEIGHT	
		(947)	(lb)		

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973
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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-07-00	MONITORS	1	UNIT	XUV MONITOR OPTICAL-MECHANICAL ASSEMBLY	SOLAR TELESCOPE GROUP
		1.43X.26 X.24	m	SIZE	
		45.3 (100)	kg (lb)	WEIGHT	
		2	w	POWER	
		1	UNIT	CONTROL UNIT	
		10	w	POWER	
		37X37X 16	cm	SIZE	
		11 (24)	kg (lb)	TOTAL WEIGHT	
		1	UNIT	XRT MONITOR	SOLAR TELESCOPE GROUP
		20DX 122L	cm	SIZE	
		45.3 (100)	kg (lb)	TOTAL WEIGHT	
		1	UNIT	H-ALPHA MONITOR	SOLAR TELESCOPE GROUP
		15	W	POWER	
		160X35.5 X25.4	cm	SIZE	
		56 (124)	kg (lb)	TOTAL WEIGHT	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-01-07-00 (CON'T)	MONITORS (CON'T)	1	UNIT	FIELD VIEWING	IR TELESCOPE (ONLY)
		30	w	POWER	
		15X15X 94	cm	SIZE	
		48 (106)	kg (lb)	TOTAL WEIGHT	

STUDY TITLE ASMDS
CONTRACT NO. NAS8-28144

TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 5

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-00-00	ARRAYS	1	UNIT	LARGE AREA X-RAY DETECTOR	
		1	UNIT	WIDE COVERAGE X-RAY DETECTOR	
		1	UNIT	LARGE MODULATION COLLIMATOR	
		1	UNIT	NARROW BAND SPEC-TROMETER/POLARI-METER	
		1	UNIT	COLLIMATED PLANE CRYSTAL SPECTRO-METER	
		1	UNIT	GAMMA-RAY SPECTRO-METER	
		1	UNIT	LOW BACKGROUND GAMMA-RAY DETECTOR	
		1	UNIT	PROTON FLUX DETECTOR	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-01-00	LARGE AREA X-RAY DETECTOR	0.1 TO 100	KEV	ENERGY BAND	
		1.15	deg	FIELD OF VIEW	
		6	UNIT	DETECTOR MODULES	
		1	UNIT	DATA PROCESSOR	
		2.4X1.8 X0.5	m	SIZE	
		315	kg	TOTAL WEIGHT	
		(695)	(lb)		

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WBS LEVEL 6

DATE MARCH 1973
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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-02-00	WIDE COVERAGE X-RAY DETECTOR(S)	2 TO 200	KEV	ENERGY BAND	
		180	deg	FIELD OF VIEW	
		154	UNIT	DETECTOR	DIVIDED INTO TWO QUARTER-SPHERES FOR HEMISPHERI-CAL COVERAGE
		1	UNIT	DATA PROCESSOR	
		1.2X2D	m	SIZE	
		250 (550)	kg (1b)	TOTAL WEIGHT	

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WBS LEVEL 6

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-03-00	LARGE MODULATION COLLIMATOR	0.1 TO 100	KEV	ENERGY BAND	
		2.9	deg	FIELD OF VIEW	
		6	UNIT	DETECTOR MODULES	
		1	UNIT	DATA PROCESSOR	
		1	UNIT	GAS SUPPLY	ARGON/CARBON DIOXIDE
		2.9X2.3 X0.85	m	SIZE	
		375	kg	TOTAL WEIGHT	
		(826)	(lb)		

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WBS LEVEL 6

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-04-00	NARROW BAND SPECTROMETER/ POLARIMETER	5.94 TO 8.37	KEV	ENERGY BAND	(NINE SPECIFIC EMISSIONS)
		1.0	deg	FIELD OF VIEW	
		9	UNIT	DETECTOR MODULES	
		1	UNIT	DATA PROCESSOR	
		2.5X2.5 X0.6	m	SIZE	
		543	kg	TOTAL WEIGHT	
		(1197)	(lb)		

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WBS LEVEL 6

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-05-00	COLLIMATED PLANE CRYSTAL SPECTROMETER	0.5 TO 10	KEV	ENERGY BAND	
		30	deg	FIELD OF VIEW	
		3	UNIT	DETECTOR MODULES	
		1	UNIT	DATA PROCESSOR	
		1.22X 1.33X 1.84	m	SIZE	
		260.8	kg	TOTAL WEIGHT	
		(574)	(lb)		

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01-001-05-02-06-00	GAMMA RAY SPECTROMETER	0.06 TO 10	MEV	ENERGY BAND	
		72	deg	FIELD OF VIEW	
		1	UNIT	DETECTOR	
		1	UNIT	CRYO REFRIGERATOR	
		1	UNIT	DATA PROCESSOR	
		0.34X 0.34X x 0.7	m	SIZE	
		155 (341)	kg (1b)	TOTAL WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-07-00	LOW BACKGROUND GAMMA RAY DETECTOR	0.3 TO 10	MEV	ENERGY BAND	
		110	deg	FIELD OF VIEW	
		4	UNIT	DETECTOR MODULES	
		1	UNIT	DATA PROCESSOR	
		1.4X1.4 X0.5	m	SIZE	
		994	kg	TOTAL WEIGHT	
		(2190)	(lb)		

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WBS LEVEL 6

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-02-08-00	PROTON FLUX DETECTOR	-	-	HIGH ENERGY ALERT	WARNS OF SOUTH ATLANTIC ANOMALY
		90	deg	FIELD OF VIEW	(TWO 45° CONES)
		0.4X0.4 X0.4	m	SIZE	
		13.5 (30)	kg (lb)	TOTAL WEIGHT	

STUDY TITLE ASTRONOMY SORTIE MISSION DEFINITION STUDY
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WBS LEVEL 5 & 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-00-00	POINTING & CONTROL SYSTEM	1	UNIT PER PAYLOAD		
01-001-05-03-01-00	CMG ASSEMBLY	1	ASSEMBLY PER PAY-LOAD	3 DG CMGS 3 INVERTERS 1 IMU	
01-001-05-03-02-00	COMMON MOUNT ACTUATORS	2	UNITS PER PAYLOAD	AZIMUTH POINTING DEPLOYMENT	
01-001-05-03-03-00	TELESCOPE GIMBAL ACTUATORS	1	UNIT PER PAYLOAD	ELEVATION POINTING & STABILITY AZIMUTH STABILITY ROLL	
		1	UNIT PER SOLAR PAYLOAD	ELEVATION POINTING & STABILITY AZI-MUTH STABILITY ROLL PITCH & YAW (COR-ONAGRAPHS)	
01-001-05-03-04-00	ARRAY PLATFORM ACTUATORS	1	UNIT PER STELLAR PAYLOAD	ELEVATION POINTING	

STUDY TITLE ASTRONOMY SORTIE MISSION DEFINITION STUDY
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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 5 & 6

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-05-00	REFERENCE ASSEMBLY	1	UNIT PER PAYLOAD	STRAPDOWN STAR TRACKERS	2 SETS OF 4 FOR SOLAR PAYLOAD; 1 SET OF 4 FOR STELLAR PAYLOADS.
				TELESCOPE IMU	2 REQ'D FOR SOLAR 1 REQ'D FOR STEL-LAR
				FINE SUN SENSOR	CORONAGRAPHS
				PRECISION BORE-SIGHTED STAR TRACKER	IR TELESCOPE
				CORRELATION TRACKER	SOLAR GROUP

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WBS LEVEL 5&6

WBS IDENTIFICATION (1) NUMBER	WBS IDENTIFICATION (2)	QUANTITY OR (3) VALUE	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-03-06-00	UV GYRO PACKAGE	1	ASSEMBLY PER UV PAYLOAD		SMALL UV ONLY
01-001-05-03-07-00	UV OUTER GIMBAL MOUNT ACTUATORS	1	SET PER UV PAYLOAD	ELEVATION, POINTING & STABILITY; AZIMUTH STABILITY	
01-001-05-03-08-00	UV REFERENCE ASSEMBLY	1	UNIT PER UV PAYLOAD	VIDICON CAMERA REFERENCE CAMERA (16 MM) SUN-EARTH SENSOR RADIATION DETECTOR	

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WBS LEVEL 6 & 7

DATE MARCH 1973

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-01-00	CMG ASSEMBLY	1	ASSEMBLY PER PAYLOAD		
		150	WATTS	AVERAGE POWER	
01-001-05-03-01-01	DOUBLE GIMBAL CMGS	3	UNITS		SKYLAB
		2300	ft-lb-sec	MOMENTUM CAPABILITY PER CMG	TOTAL MOMENTUM OF 6900 ft-lb-sec
		191 (420)	kg (lb)	UNIT WEIGHT	
01-001-05-03-01-02	INVERTERS	3	UNITS		SKYLAB
		25 (55)	kg (lb)	UNIT WEIGHT	INCLUDES INVERTER HEATERS
01-001-05-03-01-03	IMU	1	UNIT		ELECTRONICS TO INTEGRATE RATE AND ATTITUDE DATA OF SHUTTLE
		6.8 (15)	kg (lb)	UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-02-00	COMMON MOUNT ACTUATORS	2	UNITS PER PAYLOAD		
01-001-05-03-02-01	AZIMUTH POINTING	1	UNIT	ROLLING ELEMENT BEARING TYPE	
		11	ft-lb	STALL TORQUE	
		5	sec	POSITION INDICATION ACCURACY	
		15.9 (35)	kg (lb)	UNIT WEIGHT	
01-001-05-03-02-02	DEPLOYMENT	2	UNITS	ROLLING ELEMENT BEARING TYPE	
		90	ft-lb	STALL TORQUE	
		30	min	POSITION INDICATION ACCURACY	
		13.6 (30)	kg (lb)	UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-03-00	TELESCOPE GIMBAL ACTUATORS	1 (SEE NOTE)	SET PER PAYLOAD	USE FOR IR, S III, OR PHG	ADDITIONAL SET REQUIRED FOR SOLAR GROUP
01-001-05-03-03-01	ELEVATION POINTING & STABILITY	2	UNITS	ROLLING ELEMENT ELEVATION; FLEX PIVOT STABILIZATION	
		11	ft-lb	STALL TORQUE ELEVATION	
		7	ft-lb	STALL TORQUE STABILIZATION	
		5	sec	POSITION INDICATION ACCURACY	
		28.1 (62)	kg (lb)	UNIT WEIGHT	
01-001-05-03-03-02	AZIMUTH STABILITY	2	UNITS	FLEX PIVOT BEARING	
		7	ft-lb	STALL TORQUE	
		5	sec	POSITION INDICATION ACCURACY	
		15.9 (35)	kg (lb)	UNIT WEIGHT	

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TECHNICAL CHARACTERISTICS DATA FORM B

WBS LEVEL 6 & 7

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-03-03	ROLL	1	UNIT	ROLLING ELEMENT BEARING	
		2.7	ft-lb	STALL TORQUE	
		30	min	POSITION INDICATION ACCURACY	
		8.6 (19)	kg (lb)	UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-03-00	TELESCOPE GIMBAL ACTUATORS	1 (SEE NOTE)	SET	USE FOR SOLAR GROUP TELESCOPES	SEE OTHER SET REQUIRED FOR IR, SIII OR PHG
01-001-05-03-03-01	ELEVATION POINTING & STABILITY	2	UNITS	ROLLING ELEMENT ELEVATION; FLEX PIVOT STABILIZATION	
		11	ft-lb	STALL TORQUE ELEVATION	
		7	ft-lb	STALL TORQUE STABILIZATION	
		5	sec	POSITION INDICATION ACCURACY	
		28.1 (62)	kg (lb)	UNIT WEIGHT	
01-001-05-03-03-02	AZIMUTH STABILITY	2	UNITS	FLEX PIVOT BEARING	
		7	ft-lb	STALL TORQUE	
		5	sec	POSITION INDICATOR ACCURACY	
		15.9 (35)	kg (lb)	UNIT WEIGHT	
01-001-05-03-03-03	ROLL	1	UNIT	ROLLING ELEMENT BEARING	
		2.7	ft-lb	STALL TORQUE	
		30	min	POSITION INDICATION ACCURACY	
		8.6 (19)	kg (lb)	UNIT WEIGHT	

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01-001-05-03-03-04	PITCH & YAW	2	UNITS	CORONAGRAPHS	
		9.1 (20)	kg (lb)	UNIT WEIGHT	
01-001-05-03-04-00	ARRAY PLATFORM ACTUATOR	1	SET	USE ON STELLAR PAYLOADS FOR ARRAYS	NOT REQUIRED FOR SOLAR
01-001-05-03-04-01	ELEVATION POINTING	2	UNITS	ROLLING ELEMENT BEARING	
		11	ft-lb	STALL TORQUE	
		5	sec	POSITION INDICATION ACCURACY	
		13.6 (30)	kg (lb)	UNIT WEIGHT	

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01-001-05-03-05-00	REFERENCE ASSEMBLY	1 (SEE NOTE)	UNIT		SECOND UNIT WITH FINE SUN SENSOR & CORRELATION TRACKER REQUIRED FOR SOLAR
01-001-05-03-05-01	STRAPDOWN STAR TRACKERS	4	UNITS	OPTICS & ELECTRONICS	
		15 (33)	kg (lb)	UNIT WEIGHT	
01-001-05-03-05-02	TELESCOPE IMU	1	UNIT	ELECTRONICS	
		6.8 (15)	kg (lb)	UNIT WEIGHT	
01-001-05-03-05-03	FINE SUN SENSOR	1	UNIT	OPTICAL-MECHANICAL; PREAMP ASSEMBLY; SIGNAL CONDITIONER; CONTROL ELECTRONICS ASSEMBLY	REQUIRED FOR CORONAGRAPHS ONLY. ATM
		11	watts	POWER	
		24.5 (54)	kg (lb)	UNIT WEIGHT	INCLUDES ELECTRONICS
01-001-05-03-05-04	PRECISION BORESIGHTED STAR TRACKER	1	UNIT		REQUIRED FOR IR TELESCOPE ONLY
		11.3 (25)	kg (lb)	UNIT WEIGHT	
01-001-05-03-05-05	CORRELATION TRACKER	1	UNIT		REQUIRED FOR SOLAR GROUP ONLY
		25	watts	POWER	
		54.5 (120)	kg (lb)	UNIT WEIGHT	

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01-001-05-03-06-00	UV GYRO PACKAGE	1	ASSEMBLY	PER UV PAYLOAD	
		7.25	KG	UNIT WEIGHT	
		(16)	(LB)		
		165	WATTS	PEAK POWER	
01-001-05-03-07-00	UV OUTER GIMBAL MOUNT ACTUATORS	1	SET	PER UV PAYLOAD	
01-001-05-03-07-01	ELEVATION POINTING & STABILITY	2	UNITS	ROLLING ELEMENT ELEVATION; FLEX PIVOT STABILIZATION	
		15.9	KG	UNIT WEIGHT	
		(35)	(LB)		
01-001-05-03-07-02	AZIMUTH STABILITY	2	UNITS	FLEX PIVOT BEARING	
		9.1	KG	UNIT WEIGHT	
		(20)	(LB)		

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-03-08-00	UV REFERENCE ASSEMBLY	1	UNIT	PER UV PAYLOAD	
01-001-05-03-08-01	VIDICON CAMERA	1	UNIT	STAR FIELD OBSERVATION	
		3.4 (7.5)	KG (LB)	UNIT WEIGHT	
01-001-05-03-08-02	REFERENCE CAMERA	1	UNIT	16 MM	
		1.13 (2.5)	KG (LB)	UNIT WEIGHT	
01-001-05-03-08-03	SUN-EARTH SENSOR	1	UNIT		
		0.9 (2)	KG (LB)	UNIT WEIGHT	
01-001-05-03-08-04	RADIATION DETECTOR	1	UNIT	SAA & LYMAN-ALPHA	
		3.63 (8)	KG (LB)	UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-04-00-00	STRUCTURES				
01-001-05-04-01-00	COMMON MOUNT ASSEMBLY	2	ASSEMBLIES PER PAYLOAD	1 AZIMUTH TABLE 1 AZIMUTH YOKE 1 DEPLOYMENT YOKE 2 DEPLOYMENT GEARMOTORS & LAUNCH LOCKS 1 SET JETTISON EQUIPMENT	
01-001-05-04-02-00	TELESCOPE GIMBAL ASSEMBLY	1 (SEE NOTE)	ASSEMBLY PER PAYLOAD	1 OUTER GIMBAL RING 1 OUTER ROLL RING 1 INNER ROLL RING 1 ROLL GEAR 1 TELESCOPE P&C PLATFORM 1 SET GIMBAL GEARMOTORS & LAUNCH LOCKS	SOLAR PAYLOAD REQUIRES TWO ASSEMBLIES
01-001-05-04-03-00	ARRAY PLATFORM ASSEMBLY	1 (SEE NOTE)	ASSEMBLY PER PAYLOAD	1 ARRAY MOUNT 1 SET PLATFORM GEARMOTORS & LAUNCH LOCKS	REQUIRED FOR STELLAR PAYLOADS ONLY

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01-001-05-04-04-00	SUPPORT EQUIPMENT SET	1	SET PER PAYLOAD	3 CMG SUPPORT STRUCTURES	REQUIRED FOR ALL PAYLOADS
				1 SET WIDE COVERAGE X-RAY DETECTOR SUPPORTS	REQUIRED FOR STELLAR PAYLOADS ONLY
				1 GAMMA RAY SPECTROMETER HOUSING AND EXTENSION MECHANISM	REQUIRED FOR STELLAR PAYLOADS ONLY
01-001-05-04-05-00	SOLAR TELESCOPE HOUSING ASSEMBLY	1	UNIT	1 TUBULAR STRUCTURE 2 BULKHEADS 1 FIBERGLASS SUNSHIELD 6 APERTURE DOORS 6 APERTURE DOOR ACTUATORS	REQUIRED FOR SOLAR GROUP ONLY

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01-001-05-04-06-00	UV INSTRUMENT MOUNT ASSEMBLY	1	ASSEMBLY PER UV PAYLOAD		
01-001-05-04-07-00	UV INSTRUMENT PLATFORM	1	ASSEMBLY PER UV PAYLOAD		

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-04-01-00	COMMON MOUNT ASSEMBLY	2	ASSEMBLIES PER PAYLOAD		
01-001-05-04-01-01	AZIMUTH TABLE	1	UNIT	BASIC STRUCTURE WITHOUT ACTUATORS	
		0.69x 1.27x 1.27	m	ENVELOPE SIZE	
		111 (244)	kg (lb)	UNIT WEIGHT	
01-001-05-04-01-02	AZIMUTH YOKE	1	UNIT	BASIC STRUCTURE WITHOUT ACTUATORS	
		1.01x 2.54x 3.35	m	ENVELOPE SIZE	
		172 (380)	kg (lb)	UNIT WEIGHT	
01-001-05-04-01-03	DEPLOYMENT YOKE	1	UNIT	BASIC STRUCTURE WITHOUT ACTUATORS	
		0.31x 4.0 x 3.1	m	ENVELOPE SIZE	
		76 (168)	kg (lb)	UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-04-01-04	DEPLOYMENT GEARMOTORS & LAUNCH LOCKS	2 23.6 (52)	UNITS kg (lb)	UNIT WEIGHT	INCLUDES GIMBAL RING SUPPORTS
01-001-05-04-01-05	JETTISON EQUIPMENT	1 20.4 (45)	UNIT kg (lb)	UNIT WEIGHT	
01-001-05-04-02-00	TELESCOPE GIMBAL ASSEMBLY	1 (SEE NOTE)	ASSEMBLY PER PAY-LOAD		SOLAR PAYLOAD RE-QUIRES 2 ASSEMBLIES
01-001-05-04-02-01	OUTER GIMBAL RING	1 100 (220)	UNIT kg (lb)	ALUMINUM RING UNIT WEIGHT	
01-001-05-04-02-02	OUTER ROLL RING	1 133 (294)	UNIT kg (lb)	ALUMINUM RING UNIT WEIGHT	
01-001-05-04-02-03	INNER TOLL RING	1 84.3 (186)	UNIT kg (lb)	ALUMINUM RING UNIT WEIGHT	
01-001-05-04-02-04	ROLL GEAR	1 6.4 (14)	UNIT kg (lb)	UNIT WEIGHT	
01-001-05-04-02-05	TELESCOPE P&C PLATFORM	1 30.4 (67)	UNIT kg (lb)	UNIT WEIGHT	

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01-001-05-04-02-06	GIMBAL GEARMOTORS & LAUNCH LOCKS	2 24.5 (54)	UNITS kg (lb)	UNIT WEIGHT	
01-001-05-04-03-00	ARRAY PLATFORM ASSEMBLY	1	ASSEMBLY		REQUIRED FOR STEL-LAR PAYLOADS ONLY
01-001-05-04-03-01	ARRAY MOUNT	1 200 (440)	UNIT kg (lb)	BASIC STRUCTURE WITHOUT ACTUATORS UNIT WEIGHT	
01-001-05-04-03-02	PLATFORM GEARMOTORS & LAUNCH LOCKS	2 24 (53)	UNITS kg (lb)	UNIT WEIGHT	

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WBS LEVEL 6 & 7

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-04-04-00	SUPPORT EQUIPMENT SET	1	SET PER PAYLOAD		
01-001-05-04-04-01	CMG SUPPORT STRUCTURES	3	UNITS PER SET	BASIC STRUCTURE	
		14.7 (32.5)	kg (lb)	UNIT WEIGHT	INCLUDES INVERTER SUPPORT STRUCTURES
01-001-05-04-04-02	WIDE COVERAGE X-RAY DETECTOR MOUNT	2	UNITS PER SET	BASIC STRUCTURE	REQUIRED FOR STELLAR PAYLOADS ONLY
		77 (170)	kg (lb)	UNIT WEIGHT	
01-001-05-04-04-03	GAMMA RAY SPECTROMETER HOUSING AND EXTENSION MECHANISM	1	UNIT	BASIC STRUCTURE	REQUIRED FOR STELLAR PAYLOADS 3AC & 4AC ONLY
		476 (1050)	kg (lb)	UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-04-05-00	SOLAR TELESCOPE HOUSING ASSEMBLY	1	ASSEMBLY	BASIC STRUCTURE	REQUIRED FOR SOLAR GROUP ONLY
01-001-05-04-05-01	TUBULAR STRUCTURE	1 302 (290)	UNIT kg (lb)	BASIC STRUCTURE UNIT WEIGHT	
01-001-05-04-05-02	BULKHEADS	1 132 (290)	UNITS kg (lb)	BASIC STRUCTURE UNIT WEIGHT	INCLUDES FITTINGS AND PARTITIONS
01-001-05-04-05-03	FIBER GLASS SUNSHIELD	1 30.4 (67)	UNIT kg (lb)	UNIT WEIGHT	
01-001-05-04-05-04	APERTURE DOORS	6 1.81 (4)	UNITS kg (lb)	BASIC STRUCTURE UNIT WEIGHT	
01-001-05-04-05-05	DOOR ACTUATORS	6 0.91 (2)	UNITS kg (lb)	ELECTRO-MECHANICAL UNIT WEIGHT	

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WBS LEVEL 6&7

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-04-06-00	UV INSTRUMENT MOUNT ASSEMBLY	1	ASSEMBLY	PER UV PAYLOAD	
01-001-05-04-06-01	AZIMUTH TABLE	1 38.9 (78)	UNIT KG (LB)	BASIC STRUCTURE WITHOUT ACTUATORS UNIT WEIGHT	
01-001-05-04-06-02	AZIMUTH YOKE	1 59 (130)	UNIT KG (LB)	BASIC STRUCTURE WITHOUT ACTUATORS UNIT WEIGHT	
01-001-05-04-06-03	LAUNCH LOCKS	1 29.5 (65)	UNIT KG (LB)	UNIT WEIGHT	
01-001-05-04-06-04	JETTISON EQUIPMENT	1 23.1 (51)	UNIT KG (LB)	UNIT WEIGHT	
01-001-05-04-06-05	AZIMUTH GEAR-MOTORS	1 9.1 (20)	UNIT KG (LB)	AZIMUTH DRIVE UNIT WEIGHT	
01-001-05-04-06-06	FITTINGS AND FIXTURES	1 8.2 (18)	UNIT KG (LB)	UNIT WEIGHT	

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WBS IDENTIFICATION (1) NUMBER	WBS IDENTIFICATION (2)	QUANTITY OR (3) VALUE	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-04-07-00	UV INSTRUMENT PLATFORM	1	ASSEMBLY	PER UV PAYLOAD	
01-001-05-04-07-01	EQUIPMENT PLATFORM	2 2.27 (5)	UNITS KG (LB)	MACHINED ALUMINUM BRACKET UNIT WEIGHT	
01-001-05-04-07-02	GIMBAL RING	1 33.3 (73.5)	UNIT KG (LB)	ALUMINUM RING UNIT WEIGHT	
01-001-05-04-07-03	OUTER ROLL RING	1 44.5 (99.4)	UNIT KG (LB)	ALUMINUM RING UNIT WEIGHT	
01-001-05-04-07-04	INNER ROLL RING	1 30 (66.2)	UNIT KG (LB)	ALUMINUM RING UNIT WEIGHT	
01-001-05-04-07-05	PLATFORM GEAR-MOTORS	1 5.0 (11)	UNIT KG (LB)	ROLL DRIVE UNIT WEIGHT	
01-001-05-04-07-06	FITTINGS AND FIXTURES	1 11.3 (24.9)	UNIT KG (LB)	 UNIT WEIGHT	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-05-00-00	ELECTRONIC				
01-001-05-05-01-00	CONTROL & DISPLAY	1	UNIT	1 CB/DISTRIBUTOR PANEL 2 MULTIPURPOSE CRTs 1 SYMBOL GENERATOR 1 FUNCTION KEY-BOARD 1 ALPHANUMERIC KEYBOARD 2 KEYBOARD ENCODERS 1 MICROFILM VIEWER 1 EVENT TIMER 1 MISSION TIMER 1 THREE AXIS CONTROLLER 2 ANNUNCIATOR BANKS 1 RECORDER	EQUIPMENT IS IN-STALLED IN SORTIE LAB FOR ALL PAYLOADS
01-001-05-05-02-00	ELECTRICAL	1	UNIT	6 LOAD CENTER SWITCHES - FEEDER CALBES 1 JUNCTION BOX	REQUIRED FOR ALL PAYLOADS
01-001-05-05-03-00	DATA	1	UNIT	4 DATA BUS INTER-FACE UNIT 1 COAX DATA BUS 1 PALLET INSTR BOX 4 DATA PROCESSOR	REQUIRED FOR ALL PAYLOADS

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-05-04-00	UV INSTRUMENT CONTROL & DISPLAY	1	UNIT PER UV PAYLOAD	SWITCH & STATUS PANELS	LOCATED IN CREW COMPARTMENT
		16.3 (36)	KG (LB)	UNIT WEIGHT	
		44	WATTS	AVERAGE POWER	
01-001-05-05-05-00	UV INSTRUMENT ELECTRICAL	1	UNIT PER UV PAYLOAD	LOAD CENTER SWITCH FEEDER CABLES JUNCTION BOX	
01-001-05-05-06-00	UV INSTRUMENT DATA	1	UNIT PER UV PAYLOAD	TELEMETRY PROGRAMMER MINI-COMPUTER	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-05-01-00	CONTROL & DISPLAY	1	UNIT PER PAYLOAD	INTEGRATED CONCEPT	INSTALLED IN SORTIE LAB
		415	W	POWER	
		149 (329)	kg (lb)	UNIT WEIGHT	
01-001-05-05-01-01	CB/DISTRIBUTOR PANEL	1	UNIT		
01-001-05-05-01-02	MULTIPURPOSE CRTs	2	UNITS	VIDEO	ALPHANUMERIC STATIC GRAPHIC
01-001-05-05-01-03	SYMBOL GENERATOR	1	UNIT	GENERATE SYMBOLS, CHARACTERS, VECTORS, RASTER VIDEO	
01-001-05-05-01-04	FUNCTION KEYBOARD	1	UNIT	FUNCTIONAL CATEGORY DATA	
01-001-05-05-01-05	ALPHANUMERIC KEYBOARD	1	UNIT		
01-001-05-05-01-06	KEYBOARD ENCODERS	2	UNITS		
01-001-05-05-01-07	MICROFILM VIEWER	1	UNIT	READ PROCEDURAL TYPE DATA	
01-001-05-05-01-08	EVENT TIMER	1	UNIT		
01-001-05-05-01-09	MISSION TIMER	1	UNIT		
01-001-05-05-01-10	THREE-AXIS CONTROLLER	1	UNIT	INSTRUMENT POINTING	
01-001-05-05-01-11	ANNUNCIATOR BANK	2	UNITS	VISUAL ALERTING	
01-001-05-05-01-12	RECORDER	1	UNIT	MULTI CHANNEL	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-05-02-00	ELECTRICAL				
01-001-05-05-02-01	LOAD CENTER SWITCH	6	UNITS		
		10 x 5 x 20	CM	SIZE	
			W	POWER	
		2.72 (6)	kg (lb)	UNIT WEIGHT	
01-001-05-05-02-02	FEEDER CABLES	70 (155)	kg (lb)	PAYLOAD WEIGHT SOLAR	
		60 (133)	kg (lb)	PAYLOAD WEIGHT STELLAR	
01-001-05-05-02-03	JUNCTION BOX	1	UNIT		
		4.54 (10)	kg (lb)	WEIGHT	

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-05-03-00	DATA				
01-001-05-05-03-01	DATA BUS INTERFACE UNIT	4	UNITS	REMOTE COMMAND & MULTIPLEXING	ALL PAYLOADS
		9.5	W	POWER	
		10 x 8 x 18	CM	EVNELOPE SIZE	
		1.81 (4)	kg (lb)	UNIT WEIGHT	
01-001-05-05-03-02	COAX DATA BUS	122	M	LENGTH	ALL PAYLOADS
		9.1 (20)	kg (lb)	PAYLOAD WEIGHT	
01-001-05-05-03-03	PALLET INSTRUMENTATION BOX	1	UNIT	STATUS AND DYNAMIC ENVIRONMENT MONITOR	ALL PAYLOADS
		5.0	watts	POWER	
		2.26 (5)	kg (lb)	UNIT WEIGHT	
01-001-05-05-03-04	DATA PROCESSOR	4	UNITS		ALL PAYLOADS
		3.0	watts	POWER	
		2.26 (5)	kg (lb)	UNIT WEIGHT	

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-05-05-00	UV INSTRUMENT ELECTRICAL	1	UNIT	PER UV PAYLOAD	
01-001-05-05-05-01	LOAD CENTER SWITCH	1	UNIT		
		2.72	KG	UNIT WEIGHT	
		(6)	(LB)		
		4	WATTS	UNIT POWER	
01-001-05-05-05-02	FEEDER CABLES	1	SET		
		6.35	KG	SET WEIGHT	
		(14)	(LB)		
01-001-05-05-05-03	JUNCTION BOX	1	UNIT		
		3.16	KG	UNIT WEIGHT	
		(7)	(LB)		
01-001-05-05-06-00	UV INSTRUMENT DATA	1	UNIT	PER UV PAYLOAD	
01-001-05-05-06-01	TELEMETRY	1	ASSEMBLY	PROCESSOR/INTERFACE	
		1.36	KG	UNIT WEIGHT	
		(3.0)	(LB)		
		6	WATTS	UNIT POWER	
01-001-05-05-06-02	PROGRAMMER	1	ASSEMBLY		
		4.53	KG	UNIT WEIGHT	
		(10)	(LB)		
		10	WATTS	UNIT POWER	
01-001-05-05-06-03	MINI-COMPUTER	1	ASSEMBLY		
		3.63	KG	UNIT WEIGHT	
		(8)	(LB)		
		4	WATTS	UNIT POWER	

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-06-00-00	THERMAL CONTROL	1	UNIT		ALL PAYLOADS
01-001-05-06-01-00	THERMAL COATING			293 TYPE WHITE PAINT	APPLIED TO ALL SURFACES OF DEPLOYMENT YOKE
		5.45 (12)	kg (lb)	PAYLOAD WEIGHT	
01-001-05-06-02-00	MULTILAYER INSULATION			PALLET EQUIPMENT	ALL PAYLOADS
		59 (130)	kg (lb)	PAYLOAD WEIGHT	
				SOLAR TELESCOPE HOUSING	SOLAR PAYLOAD ONLY
		62.1 (137)	kg (lb)	PAYLOAD WEIGHT	
				ARRAY PLATFORM	STELLAR PAYLOADS ONLY
		22.6 (50)	kg (lb)	PAYLOAD WEIGHT	

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WBS LEVEL 5

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-07-00-00	SMALL UV TELESCOPES	2	UNITS	SIX-INCH SURVEY CAMERAS (TIFFT)	TWIN CAMERAS
		1	UNIT	ALL-REFLECTIVE SPECTROGRAPH (MORTON)	
		1	UNIT	10 CM IMAGE CONVERTING SPECTROGRAPH (CARRUTHERS)	
		1	UNIT	15 CM IMAGE CONVERTING SPECTROGRAPH (CARRUTHERS)	
		1	UNIT	40 CM INTERNAL GRATING SPECTROGRAPH (CARRUTHERS)	
		1	UNIT	40 CM IMAGING CAMERA (CARRUTHERS)	
		1	UNIT	ECHELLE SPECTROGRAPH (MORTON)	
		1	UNIT	SCANNING SPECTROMETER (KONDO)	

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WBS LEVEL 6

WBS IDENTIFICATION (1) NUMBER	WBS IDENTIFICATION (2)	QUANTITY OR (3) VALUE	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-07-01-00	SIX-INCH SURVEY CAMERAS (TIFFT)	15	CM	APERTURE	MEINEL-SHACK
		0.08 (5)	RADIAN (DEGREES)	FIELD OF VIEW	FILM SENSOR
		f/2		SYSTEM F NUMBER	
		170 TO 300	NANOMETERS	SPECTRAL RANGE	
		7.3×10^{-5} (15)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		75	WATTS	AVERAGE POWER	
		0.4 X 0.3 D (16 X 12 D)	METER (INCHES)	SIZE	
		75 (166)	KG (LB)	TOTAL WEIGHT	
		29×10^{-4} (10)	RADIAN (ARC MIN)	POINTING ACCURACY	
		5.8×10^{-5} (12)	RADIAN (ARC SEC)	STABILITY	
		60 TO 900	SECONDS	STABILITY DURATION	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-07-02-00	ALL-REFLECTIVE SPECTROGRAPH (MORTON)	5	CM	APERTURE	PRIME FOCUS
		0.21 (12)	RADIAN (DEGREES)	FIELD OF VIEW	FILM SENSOR
		f/2		SYSTEM F NUMBER	
		90 TO 180	NANOMETERS	SPECTRAL RANGE	
		14.5×10^{-5} (30)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		56	WATTS	AVERAGE POWER	
		1.0X0.56 X0.3 (39X22 X12)	METER INCHES	SIZE	
		55 (122)	KG LB	TOTAL WEIGHT	
		29×10^{-4} (10)	RADIAN (ARC MIN)	POINTING ACCURACY	
		5.8×10^{-5} (12)	RADIAN (ARC SEC)	STABILITY	
		120 TO 1200	SECONDS	STABILITY DURATION	

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-07-03-00	10 CM IMAGE CONVERTING SPECTROGRAPH (CARRUTHERS)	10	CM	APERTURE	SCHMIDT
		0.26 (15)	RADIAN (DEGREES)	FIELD OF VIEW	ELECTRONOGRAPH SENSOR
		f/1.5		SYSTEM F NUMBER	
		120 TO 180	NANOMETERS	SPECTRAL RANGE	
		$9.7X10^{-5}$ (20)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		20	WATTS	AVERAGE POWER	
		0.89X 0.53X 0.28 (35X21 X11)	METER (INCHES)	SIZE	
		46 (101)	KG (LB)	TOTAL WEIGHT	
		$29X10^{-4}$ (10)	RADIAN (ARC MIN)	POINTING ACCURACY	
		$5.8X10^{-5}$ (12)	RADIAN (ARC SEC)	STABILITY	
		2.5 TO 625	SECONDS	STABILITY DURATION	

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(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
01-001-05-07-04-00	15 CM IMAGE CONVERTING SPECTROGRAPH (CARRUTHERS)	15	CM	APERTURE	SCHMIDT
		0.17 (10)	RADIAN (DEGREES)	FIELD OF VIEW	ELECTRONOGRAPH SENSOR
		f/2		SYSTEM F NUMBER	
		30 TO 210	NANOMETERS	SPECTRAL RANGE	
		$7.3X10^{-5}$ (15)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		30	WATTS	AVERAGE POWER	
		1.4X0.8 X0.4 (55X32 X16)	METER INCHES	SIZE	
		40 (88)	KG (LB)	TOTAL WEIGHT	
		$5.8X10^{-4}$ (2)	RADIAN (ARC MIN)	POINTING ACCURACY	
		$5.8X10^{-5}$ (12)	RADIAN (ARC SEC)	STABILITY	
		2.5 TO 625	SECONDS	STABILITY DURATION	

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WBS IDENTIFICATION (1) NUMBER	WBS IDENTIFICATION (2)	QUANTITY OR (3) VALUE	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-07-05-00	40 CM INTERNAL GRATING SPECTROGRAPH (CARRUTHERS)	40	CM	APERTURE	CASSEGRAIN
		0.017 (1)	RADIAN (DEGREES)	FIELD OF VIEW	ELECTRONOGRAPH SENSOR
		f/10		SYSTEM F NUMBER	
		90 TO 180	NANOMETERS	SPECTRAL RANGE	
		$5X10^{-6}$ (1)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		-	WATTS	AVERAGE POWER	
		1.7X0.5 DIA. (67X19.7 DIA)	METER (INCHES)	SIZE	
		60 (132)	KG (LB)	TOTAL WEIGHT	
		$29X10^{-4}$ (10)	RADIAN (ARC MIN)	POINTING ACCURACY	
		$5X10^{-6}$ (1)	RADIAN (ARC SEC)	STABILITY	
		60 TO 900	SECONDS	STABILITY DURATION	

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-07-06-00	40 CM IMAGING CAMERA (CARRUTHERS)	40	CM	APERTURE	CASSEGRAIN
		0.028 (1.6)	RADIAN (DEGREES)	FIELD OF VIEW	ELECTRONOGRAPH SENSOR
		f/6		SYSTEM F NUMBER	
		90 TO 210	NANOMETERS	SPECTRAL RANGE	
		$5X10^{-6}$ (1)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		-	WATTS	AVERAGE POWER	
		1.3X0.5 DIA (51X19.7 DIA)	METER (INCHES)	SIZE	
		60 (132)	KG (LB)	TOTAL WEIGHT	
		$29X10^{-4}$ (10)	RADIAN (ARC MIN)	POINT ACCURACY	
		$5X10^{-6}$ (1)	RADIAN (ARC SEC)	STABILITY	
		60 TO 900	SECONDS	STABILITY DURATION	

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WBS IDENTIFICATION (1) NUMBER	WBS IDENTIFICATION (2)	QUANTITY OR (3) VALUE	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-07-07-00	ECHELLE SPECTROGRAPH (MORTON)	15	CM	APERTURE	PRIME FOCUS
		0.017 (1)	RADIAN (DEGREES)	FIELD OF VIEW	FILM SENSOR
		f/5		SYSTEM F NUMBER	
		120 TO 230	NANOMETERS	SPECTRAL RANGE	
		- -	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		150	WATTS	AVERAGE POWER	
		1.5X0.4 DIA (59X16 DIA)	METER (INCHES)	SIZE	
		80 (176)	KG (LB)	TOTAL WEIGHT	
		- -	RADIAN (ARC MIN)	POINTING ACCURACY	
		4.9×10^{-5} (10)	RADIAN (ARC SEC)	STABILITY	
		120 TO 1200	SECONDS	STABILITY DURATION	

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WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
01-001-05-07-08-00	SCANNING SPECTROMETER (KONDO)	40	CM	APERTURE	CASSEGRAIN
		0.0088 (0.5)	RADIAN (DEGREES)	FIELD OF VIEW	IMAGE DISSECTOR SENSOR
		f/7.5		SYSTEM F NUMBER	
		270 TO 300	NANOMETERS	SPECTRAL RANGE	
		$9.7X10^{-6}$ (2)	RADIAN (ARC SEC)	ANGULAR RESOLUTION	
		75	WATTS	AVERAGE POWER	
		1.5X0.5 X0.5 (59X19.7 X19.7)	METER (INCHES)	SIZE	
		96 (212)	KG (LB)	TOTAL WEIGHT	
		$0.6X10^{-4}$ (0.25)	RADIAN (ARC MIN)	POINTING ACCURACY	
		$5X10^{-6}$ (1)	RADIAN (ARC SEC)	STABILITY	
		15 TO 600	SECONDS	STABILITY DURATION	

E. WORK BREAKDOWN STRUCTURE (WBS) DICTIONARY AND DIAGRAM

The final WBS dictionary and diagram are presented in this section. This WBS is compatible with the breakdown that was used in estimating costs.

The dictionary (Table V-6) is a listing in numerical order of the telescopes, arrays, and instruments that are candidates for an Astronomy Sortie Missions project. Included with these items are the subsystems and their components (to level 7 when appropriate) necessary for the flight of the telescopes, arrays, and instruments.

Figure V-1 shows the relationship of these elements in a family tree. This diagram shows the payload (a level 4 item) elements to level 5 and level 6. Operations, including Launch, Mission, Support, and Recovery and Refurbishment (level 4 items) are shown to level 5.

Project elements at level 4, other than payloads and operations, are shown on the diagram, but were not priced. These level 4 items (including Project Management, System Support and Integration, Facilities, and GSE) depend on the number of payloads, number of flights, and duration of the project, which were not selected for this study.

Table V-6 WBS Dictionary

WBS IDENTIFICATION NUMBER						
LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	LEVEL 7	WBS IDENTIFICATION
0 1	0 0 0	0 0	0 0	0 0	0 0	SHUTTLE SORTIE MISSION PROGRAM
0 1	0 0 1	0 0	0 0	0 0	0 0	ASTRONOMY SORTIE MISSION PROJECT
0 1	0 0 1	0 1	0 0	0 0	0 0	PROJECT MANAGEMENT
0 1	0 0 1	0 1	0 1	0 0	0 0	PROGRAM CONTROL
0 1	0 0 1	0 1	0 2	0 0	0 0	CONFIGURATION MANAGEMENT
0 1	0 0 1	0 1	0 3	0 0	0 0	CONTRACTUAL DATA MANAGEMENT
0 1	0 0 1	0 2	0 0	0 0	0 0	SYSTEM SUPPORT & INTEGRATION
0 1	0 0 1	0 2	0 1	0 0	0 0	SYSTEMS ANALYSIS
0 1	0 0 1	0 2	0 2	0 0	0 0	PAYLOAD INTEGRATION
0 1	0 0 1	0 2	0 3	0 0	0 0	PROGRAM INTEGRATION
0 1	0 0 1	0 2	0 4	0 0	0 0	SAFETY AND RELIABILITY
0 1	0 0 1	0 2	0 5	0 0	0 0	QUALITY ASSURANCE
0 1	0 0 1	0 3	0 0	0 0	0 0	FACILITIES
0 1	0 0 1	0 3	0 1	0 0	0 0	CONTRACTOR
0 1	0 0 1	0 3	0 2	0 0	0 0	GOVERNMENT
0 1	0 0 1	0 4	0 0	0 0	0 0	GROUND SUPPORT EQUIPMENT
0 1	0 0 1	0 4	0 1	0 0	0 0	ELECTRICAL & ELECTRONIC
0 1	0 0 1	0 4	0 2	0 0	0 0	STRUCTURAL & MECHANICAL
0 1	0 0 1	0 4	0 3	0 0	0 0	OPTICAL
0 1	0 0 1	0 4	0 4	0 0	0 0	TRANSPORT & HANDLING
0 1	0 0 1	0 5	0 0	0 0	0 0	PAYLOADS
0 1	0 0 1	0 5	0 1	0 0	0 0	TELESCOPES
0 1	0 0 1	0 5	0 1	0 1	0 0	IR TELESCOPE
0 1	0 0 1	0 5	0 1	0 2	0 0	STRATOSCOPE III
0 1	0 0 1	0 5	0 1	0 3	0 0	PHOTOHELIOGRAPH
0 1	0 0 1	0 5	0 1	0 4	0 0	X-RAY TELESCOPE
0 1	0 0 1	0 5	0 1	0 5	0 0	XUV SPECTROHELIOGRAPH
0 1	0 0 1	0 5	0 1	0 6	0 0	CORONAGRAPHS
0 1	0 0 1	0 5	0 1	0 7	0 0	MONITORS
0 1	0 0 1	0 5	0 2	0 0	0 0	ARRAYS
0 1	0 0 1	0 5	0 2	0 1	0 0	LARGE AREA X-RAY DETECTOR
0 1	0 0 1	0 5	0 2	0 2	0 0	WIDE COVERAGE X-RAY DETECTOR
0 1	0 0 1	0 5	0 2	0 3	0 0	LARGE MODULATION COLLIMATOR
0 1	0 0 1	0 5	0 2	0 4	0 0	NARROW BAND SPECTRO/POLARIM
0 1	0 0 1	0 5	0 2	0 5	0 0	COLLIMATED PC SPECTROMETER
0 1	0 0 1	0 5	0 2	0 6	0 0	GAMMA-RAY SPECTROMETER
0 1	0 0 1	0 5	0 2	0 7	0 0	LOW BACKGROUND γ-RAY DETECTOR
0 1	0 0 1	0 5	0 2	0 8	0 0	PROTON FLUX DETECTOR

Table V-6 (cont)

WBS IDENTIFICATION NUMBER						
LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	LEVEL 7	WBS IDENTIFICATION
0 1	0 0 1	0 5	0 3	0 0	0 0	POINTING & CONTROL SYSTEM
0 1	0 0 1	0 5	0 3	0 1	0 0	CMG ASSEMBLY
0 1	0 0 1	0 5	0 3	0 1	0 1	DOUBLE GIMBAL CMGs
0 1	0 0 1	0 5	0 3	0 1	0 2	INVERTERS
0 1	0 0 1	0 5	0 3	0 1	0 3	IMU
0 1	0 0 1	0 5	0 3	0 2	0 0	COMMON MOUNT ACTUATORS
0 1	0 0 1	0 5	0 3	0 2	0 1	AZIMUTH POINTING
0 1	0 0 1	0 5	0 3	0 2	0 2	DEPLOYMENT
0 1	0 0 1	0 5	0 3	0 3	0 0	TELESCOPE GIMBAL ACTUATORS
0 1	0 0 1	0 5	0 3	0 3	0 1	ELEVATION POINTING & STABILITY
0 1	0 0 1	0 5	0 3	0 3	0 2	AZIMUTH STABILITY
0 1	0 0 1	0 5	0 3	0 3	0 3	ROLL
0 1	0 0 1	0 5	0 3	0 3	0 4	PITCH & YAW (CORONAGRAPHS)
0 1	0 0 1	0 5	0 3	0 4	0 0	ARRAY PLATFORM ACTUATOR
0 1	0 0 1	0 5	0 3	0 4	0 1	ELEVATION POINTING
0 1	0 0 1	0 5	0 3	0 5	0 0	REFERENCE ASSEMBLY
0 1	0 0 1	0 5	0 3	0 5	0 1	STRAPDOWN STAR TRACKERS
0 1	0 0 1	0 5	0 3	0 5	0 2	TELESCOPE IMU
0 1	0 0 1	0 5	0 3	0 5	0 3	FINE SUN SENSOR
0 1	0 0 1	0 5	0 3	0 5	0 4	BORESIGHTED STAR TRACKER-PRECISION
0 1	0 0 1	0 5	0 3	0 5	0 5	CORRELATION TRACKER
0 1	0 0 1	0 5	0 3	0 6	0 0	UV GYRO PACKAGE
0 1	0 0 1	0 5	0 3	0 7	0 0	UV OUTER GIMBAL MOUNT ACTUATORS
0 1	0 0 1	0 5	0 3	0 7	0 1	ELEVATION POINTING & STABILITY
0 1	0 0 1	0 5	0 3	0 7	0 2	AZIMUTH STABILITY
0 1	0 0 1	0 5	0 3	0 8	0 0	UV REFERENCE ASSEMBLY
0 1	0 0 1	0 5	0 3	0 8	0 1	VIDICON CAMERA
0 1	0 0 1	0 5	0 3	0 8	0 2	REFERENCE CAMERA
0 1	0 0 1	0 5	0 3	0 8	0 3	SUN-EARTH SENSOR
0 1	0 0 1	0 5	0 3	0 8	0 4	RADIATION DETECTOR
0 1	0 0 1	0 5	0 4	0 0	0 0	STRUCTURES
0 1	0 0 1	0 5	0 4	0 1	0 0	COMMON MOUNT ASSEMBLY
0 1	0 0 1	0 5	0 4	0 1	0 1	AZIMUTH TABLE
0 1	0 0 1	0 5	0 4	0 1	0 2	AZIMUTH YOKE
0 1	0 0 1	0 5	0 4	0 1	0 3	DEPLOYMENT YOKE
0 1	0 0 1	0 5	0 4	0 1	0 4	DEPLOYMENT GEARMOTORS & LAUNCH LOCKS
0 1	0 0 1	0 5	0 4	0 1	0 5	JETTISON EQUIPMENT

Table V-6 (cont)

WBS IDENTIFICATION NUMBER													
LEVEL 2		LEVEL 3			LEVEL 4		LEVEL 5		LEVEL 6		LEVEL 7		WBS IDENTIFICATION
0	1	0	0	1	0	5	0	4	0	2	0	0	TELESCOPE GIMBAL ASSEMBLY
0	1	0	0	1	0	5	0	4	0	2	0	1	OUTER GIMBAL RING
0	1	0	0	1	0	5	0	4	0	2	0	2	OUTER ROLL RING
0	1	0	0	1	0	5	0	4	0	2	0	3	INNER ROLL RING
0	1	0	0	1	0	5	0	4	0	2	0	4	ROLL GEAR
0	1	0	0	1	0	5	0	4	0	2	0	5	TELESCOPE P&C PLATFORM
0	1	0	0	1	0	5	0	4	0	2	0	6	GIMBAL GEARMOTORS & LAUNCH LOCKS
0	1	0	0	1	0	5	0	4	0	3	0	0	ARRAY PLATFORM ASSEMBLY
0	1	0	0	1	0	5	0	4	0	3	0	1	ARRAY MOUNT
0	1	0	0	1	0	5	0	4	0	3	0	2	PLATFORM GEARMOTORS & LAUNCH LOCKS
0	1	0	0	1	0	5	0	4	0	4	0	0	SUPPORT EQUIPMENT SET
0	1	0	0	1	0	5	0	4	0	4	0	1	CMG SUPPORT STRUCTURES
0	1	0	0	1	0	5	0	4	0	4	0	2	WC X-RAY DETECTOR MOUNT
0	1	0	0	1	0	5	0	4	0	4	0	3	γ-RAY SPECT HOUSING & EXT MECH
0	1	0	0	1	0	5	0	4	0	5	0	0	SOLAR TELESCOPE HOUSING ASSY
0	1	0	0	1	0	5	0	4	0	5	0	1	TUBULAR STRUCTURE
0	1	0	0	1	0	5	0	4	0	5	0	2	BULKHEADS
0	1	0	0	1	0	5	0	4	0	5	0	3	SUNSHIELD-FIBERGLASS
0	1	0	0	1	0	5	0	4	0	5	0	4	APERTURE DOORS
0	1	0	0	1	0	5	0	4	0	5	0	5	DOOR ACTUATORS
0	1	0	0	1	0	5	0	4	0	6	0	0	UV INSTRUMENT MOUNT ASSEMBLY
0	1	0	0	1	0	5	0	4	0	6	0	1	AZIMUTH TABLE
0	1	0	0	1	0	5	0	4	0	6	0	2	AZIMUTH YOKE
0	1	0	0	1	0	5	0	4	0	6	0	3	LAUNCH LOCKS
0	1	0	0	1	0	5	0	4	0	6	0	4	JETTISON EQUIPMENT
0	1	0	0	1	0	5	0	4	0	6	0	5	AZIMUTH GEARMOTORS
0	1	0	0	1	0	5	0	4	0	6	0	6	FITTINGS & FIXTURES
0	1	0	0	1	0	5	0	4	0	7	0	0	UV INSTRUMENT PLATFORM
0	1	0	0	1	0	5	0	4	0	7	0	1	EQUIPMENT PLATFORM
0	1	0	0	1	0	5	0	4	0	7	0	2	GIMBAL RING
0	1	0	0	1	0	5	0	4	0	7	0	3	OUTER ROLL RING
0	1	0	0	1	0	5	0	4	0	7	0	4	INNER ROLL RING
0	1	0	0	1	0	5	0	4	0	7	0	5	PLATFORM GEARMOTORS
0	1	0	0	1	0	5	0	4	0	7	0	6	FITTINGS & FIXTURES
0	1	0	0	1	0	5	0	5	0	0	0	0	ELECTRONIC
0	1	0	0	1	0	5	0	5	0	1	0	0	CONTROL & DISPLAY
0	1	0	0	1	0	5	0	5	0	1	0	1	CB/DISTRIBUTOR PANEL
0	1	0	0	1	0	5	0	5	0	1	0	2	MULTIPURPOSE CRT

Table V-6 (cont)

WBS IDENTIFICATION NUMBER						WBS IDENTIFICATION
LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	LEVEL 7	
						ELECTRONIC (cont)
0 1	0 0 1	0 5	0 5	0 1	0 3	SYMBOL GENERATOR
0 1	0 0 1	0 5	0 5	0 1	0 4	FUNCTION KEYBOARD
0 1	0 0 1	0 5	0 5	0 1	0 5	ALPHANUMERIC KEYBOARD
0 1	0 0 1	0 5	0 5	0 1	0 6	KEYBOARD ENCODER
0 1	0 0 1	0 5	0 5	0 1	0 7	MICROFILM VIEWER
0 1	0 0 1	0 5	0 5	0 1	0 8	EVENT TIMER
0 1	0 0 1	0 5	0 5	0 1	0 9	MISSION TIMER
0 1	0 0 1	0 5	0 5	0 1	1 0	THREE-AXIS CONTROLLER
0 1	0 0 1	0 5	0 5	0 1	1 1	ANNUNCIATOR BANK
0 1	0 0 1	0 5	0 5	0 1	1 2	RECORDER
0 1	0 0 1	0 5	0 5	0 2	0 0	ELECTRICAL
0 1	0 0 1	0 5	0 5	0 2	0 1	LOAD CENTER SWITCH
0 1	0 0 1	0 5	0 5	0 2	0 2	FEEDER CABLES
0 1	0 0 1	0 5	0 5	0 2	0 3	JUNCTION
0 1	0 0 1	0 5	0 5	0 3	0 0	DATA
0 1	0 0 1	0 5	0 5	0 3	0 1	DATA BUS INTERFACE UNIT
0 1	0 0 1	0 5	0 5	0 3	0 2	COAX DATA BUS
0 1	0 0 1	0 5	0 5	0 3	0 3	PALLET INSTRUMENTATION BOX
0 1	0 0 1	0 5	0 5	0 3	0 4	DATA PROCESSOR
0 1	0 0 1	0 5	0 5	0 4	0 0	UV INSTRUMENT CONTROL & DISPLAY
0 1	0 0 1	0 5	0 5	0 5	0 0	UV INSTRUMENT ELECTRICAL
0 1	0 0 1	0 5	0 5	0 5	0 1	LOAD CENTER SWITCH
0 1	0 0 1	0 5	0 5	0 5	0 2	FEEDER CABLES
0 1	0 0 1	0 5	0 5	0 5	0 3	JUNCTION BOX
0 1	0 0 1	0 5	0 5	0 6	0 0	UV INSTRUMENT DATA
0 1	0 0 1	0 5	0 5	0 6	0 1	TELEMETRY
0 1	0 0 1	0 5	0 5	0 6	0 2	PROGRAMMER
0 1	0 0 1	0 5	0 5	0 6	0 3	MINI-COMPUTER
0 1	0 0 1	0 5	0 6	0 0	0 0	THERMAL CONTROL
0 1	0 0 1	0 5	0 6	0 1	0 0	THERMAL COATING
0 1	0 0 1	0 5	0 6	0 2	0 0	MULTILAYER INSULATION
0 1	0 0 1	0 5	0 7	0 0	0 0	SMALL UV INSTRUMENTS
0 1	0 0 1	0 5	0 7	0 1	0 0	SIX-INCH SURVEY CAMERAS (TIFFT)
0 1	0 0 1	0 5	0 7	0 2	0 0	ALL-REFLECTIVE SPECTROGRAPH (MORTON)
0 1	0 0 1	0 5	0 7	0 3	0 0	10 CM IMAGE CONVERTING SPECTROGRAPH (CARRUTHERS)
0 1	0 0 1	0 5	0 7	0 4	0 0	15 CM IMAGE CONVERTING SPECTROGRAPH (CARRUTHERS)

Table V-6 (cont)

WBS IDENTIFICATION NUMBER														
LEVEL 2		LEVEL 3			LEVEL 4		LEVEL 5		LEVEL 6		LEVEL 7		WBS IDENTIFICATION
													SMALL UV INSTRUMENTS (cont)
0	1	0	0	1	0	5	0	7	0	5	0	0	40 CM INTERNAL GRATING SPECTROGRAPH (CARRUTHERS)
0	1	0	0	1	0	5	0	7	0	6	0	0	40 CM IMAGING CAMERA (CARRUTHERS)
0	1	0	0	1	0	5	0	7	0	7	0	0	ECHELLE SPECTROGRAPH (MORTON)
0	1	0	0	1	0	5	0	7	0	8	0	0	SCANNING SPECTROMETER (KONDO)
0	1	0	0	1	0	6	0	0	0	0	0	0	LAUNCH OPERATIONS
0	1	0	0	1	0	6	0	1	0	0	0	0	IR TELESCOPE
0	1	0	0	1	0	6	0	2	0	0	0	0	STRATOSCOPE III
0	1	0	0	1	0	6	0	3	0	0	0	0	PHOTOHELIOGRAPH
0	1	0	0	1	0	4	0	0	0	0	0	0	SOLAR GROUP
0	1	0	0	1	0	6	0	5	0	0	0	0	LARGE AREA X-RAY DETECTOR & COLLIMATED PC SPECT (GROUP E)
0	1	0	0	1	0	6	0	6	0	0	0	0	WIDE COVERAGE X-RAY DETECTOR (GROUP A)
0	1	0	0	1	0	6	0	7	0	0	0	0	LARGE MODULATION COLLIMATOR (GROUP D)
0	1	0	0	1	0	6	0	8	0	0	0	0	NARROW BAND SPECTRO/POLARIM (GROUP B)
0	1	0	0	1	0	6	0	9	0	0	0	0	GAMMA-RAY SPECTROMETER AND LOW BACK-GROUND γ-RAY DETECTOR (GROUP C)
0	1	0	0	1	0	6	1	0	0	0	0	0	UV INSTRUMENT
0	1	0	0	1	0	6	1	1	0	0	0	0	INTERMEDIATE TELESCOPES SUBSYSTEMS
0	1	0	0	1	0	6	1	2	0	0	0	0	ARRAY GROUPS SUBSYSTEMS
0	1	0	0	1	0	6	1	3	0	0	0	0	UV INSTRUMENT SUBSYSTEMS
0	1	0	0	1	0	7	0	0	0	0	0	0	MISSION OPERATIONS
0	1	0	0	1	0	7	0	1	0	0	0	0	IR TELESCOPE
0	1	0	0	1	0	7	0	2	0	0	0	0	STRATOSCOPE III
0	1	0	0	1	0	7	0	3	0	0	0	0	PHOTOHELIOGRAPH
0	1	0	0	1	0	7	0	4	0	0	0	0	SOLAR GROUP
0	1	0	0	1	0	7	0	5	0	0	0	0	LARGE AREA X-RAY DETECTOR & COLLIMATED PC SPECT (GROUP E)
0	1	0	0	1	0	7	0	6	0	0	0	0	WIDE COVERAGE X-RAY DETECTOR (GROUP A)
0	1	0	0	1	0	7	0	7	0	0	0	0	LARGE MODULATION COLLIMATOR (GROUP D)
0	1	0	0	1	0	7	0	8	0	0	0	0	NARROW BAND SPECTRO/POLARIM (GROUP B)
0	1	0	0	1	0	7	0	9	0	0	0	0	GAMMA-RAY SPECTROMETER AND LOW BACK-GROUND γ-RAY DETECTOR (GROUP C)
0	1	0	0	1	0	7	1	0	0	0	0	0	UV INSTRUMENT
0	1	0	0	1	0	7	1	1	0	0	0	0	INTERMEDIATE TELESCOPES SUBSYSTEMS
0	1	0	0	1	0	7	1	2	0	0	0	0	ARRAY GROUPS SUBSYSTEMS
0	1	0	0	1	0	7	1	3	0	0	0	0	UV INSTRUMENT SUBSYSTEMS

Table V-6 (concl)

WBS IDENTIFICATION NUMBER														
LEVEL 2		LEVEL 3			LEVEL 4		LEVEL 5		LEVEL 6		LEVEL 7		WBS IDENTIFICATION
0	1	0	0	1	0	8	0	0	0	0	0	0	SUPPORT OPERATIONS
0	1	0	0	1	0	8	0	1	0	0	0	0	IR TELESCOPE
0	1	0	0	1	0	8	0	2	0	0	0	0	STRATOSCOPE III
0	1	0	0	1	0	8	0	3	0	0	0	0	PHOTOHELIOGRAPH
0	1	0	0	1	0	8	0	4	0	0	0	0	SOLAR GROUP
0	1	0	0	1	0	8	0	5	0	0	0	0	LARGE AREA X-RAY DETECTOR & COLLIMATED PC SPECT (GROUP E)
0	1	0	0	1	0	8	0	6	0	0	0	0	WIDE COVERAGE X-RAY DETECTOR (GROUP A)
0	1	0	0	1	0	8	0	7	0	0	0	0	LARGE MODULATION COLLIMATOR (GROUP D)
0	1	0	0	1	0	8	0	8	0	0	0	0	NARROW BAND SPECTRO/POLARIM (GROUP B)
0	1	0	0	1	0	8	0	9	0	0	0	0	GAMMA-RAY SPECTROMETER AND LOW BACK-GROUND γ-RAY DETECTOR (GROUP C)
0	1	0	0	1	0	8	1	0	0	0	0	0	UV INSTRUMENT
0	1	0	0	1	0	8	1	1	0	0	0	0	INTERMEDIATE TELESCOPES SUBSYSTEMS
0	1	0	0	1	0	8	1	2	0	0	0	0	ARRAY GROUPS SUBSYSTEMS
0	1	0	0	1	0	8	1	3	0	0	0	0	UV INSTRUMENT SUBSYSTEMS
0	1	0	0	1	0	9	0	0	0	0	0	0	RECOVERY AND REFURBISHMENT OPERATIONS
0	1	0	0	1	0	9	0	1	0	0	0	0	IR TELESCOPE
0	1	0	0	1	0	9	0	2	0	0	0	0	STRATOSCOPE III
0	1	0	0	1	0	9	0	3	0	0	0	0	PHOTOHELIOGRAPH
0	1	0	0	1	0	9	0	4	0	0	0	0	SOLAR GROUP
0	1	0	0	1	0	9	0	5	0	0	0	0	LARGE AREA X-RAY DETECTOR & COLLIMATED PC SPECT (GROUP E)
0	1	0	0	1	0	9	0	6	0	0	0	0	WIDE COVERAGE X-RAY DETECTOR (GROUP A)
0	1	0	0	1	0	9	0	7	0	0	0	0	LARGE MODULATION COLLIMATOR (GROUP D)
0	1	0	0	1	0	9	0	8	0	0	0	0	NARROW BAND SPECTRO/POLARIM (GROUP B)
0	1	0	0	1	0	9	0	9	0	0	0	0	GAMMA-RAY SPECTROMETER AND LOW BACK-GROUND γ-RAY DETECTOR (GROUP C)
0	1	0	0	1	0	9	1	0	0	0	0	0	UV INSTRUMENT
0	1	0	0	1	0	9	1	1	0	0	0	0	INTERMEDIATE TELESCOPES SUBSYSTEMS
0	1	0	0	1	0	9	1	2	0	0	0	0	ARRAY GROUPS SUBSYSTEMS
0	1	0	0	1	0	9	1	3	0	0	0	0	UV INSTRUMENT SUBSYSTEMS

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VI. SUGGESTED ADDITIONAL EFFORT

In addition to the additional effort recommended during the original 9-month study (Vol I of Ref 1), the effort described below should be performed before deciding on a recommended Astronomy Sortie Mission Program.

Integration of Astronomy Working Group Requirements - The working groups for Astronomy Sortie Missions are presently defining the objectives and instruments that should be accommodated by the Shuttle sortie missions. The objectives and instruments being defined by the working groups differ significantly from those instruments considered by this study. It is recommended that additional effort be expended to convert the scientific objectives and instrument requirements into engineering requirements that would be used to identify the ancillary hardware required, interface requirements on the Shuttle, and the operations necessary to support the instruments. In addition, planning data should be developed for the various working groups to provide NASA with a broader base for planning purposes.

Integration of Sortie Mission Requirements - There are a number of studies and working groups that are defining the ancillary hardware, interfaces, and operations that are necessary for a particular sortie payload. To date, these studies have been worked independent of each other, and no effort has been made to integrate the results. It is suggested that a study be initiated to integrate the results of the sortie working groups and related study activities, thereby providing definition of the ancillary hardware, interfaces, and operations that would satisfy the sortie mode of operation in the most cost-efficient manner.

Low-Cost Payload Study - Recognizing the importance of low-cost payloads for the early sortie missions, it is recommended that a study be initiated to investigate the possibility of using existing astronomy instruments for the early sortie flights. This study would survey governmental, institutional, and industrial sources to determine astronomy instruments that are in existence and candidates for the sortie mode of operation. The results of this study would be: definition of existing instruments for sortie missions; determination of ancillary hardware necessary to accommodate the instruments; and definition of the operations required. In addition, detailed planning data should be provided for each of the candidate instruments and their accommodation requirements.

Contamination Study - Since contamination of astronomy instruments is of major concern, it is recommended that a detailed study on the cause and effect of contamination be undertaken. The purpose of the study would be to identify the possible sources of contamination for the sortie mode of operation and to determine the effects of the contamination on the astronomy instruments. Typical contamination sources that should be investigated include materials outgassing, atmosphere leakage, overboard dumps of water and waste, thruster firings, gas leakages, etc. The effects on the astronomy instruments would include the degradation of the instruments due to absorption, deposition, scattering, etc.

VII. REFERENCES

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